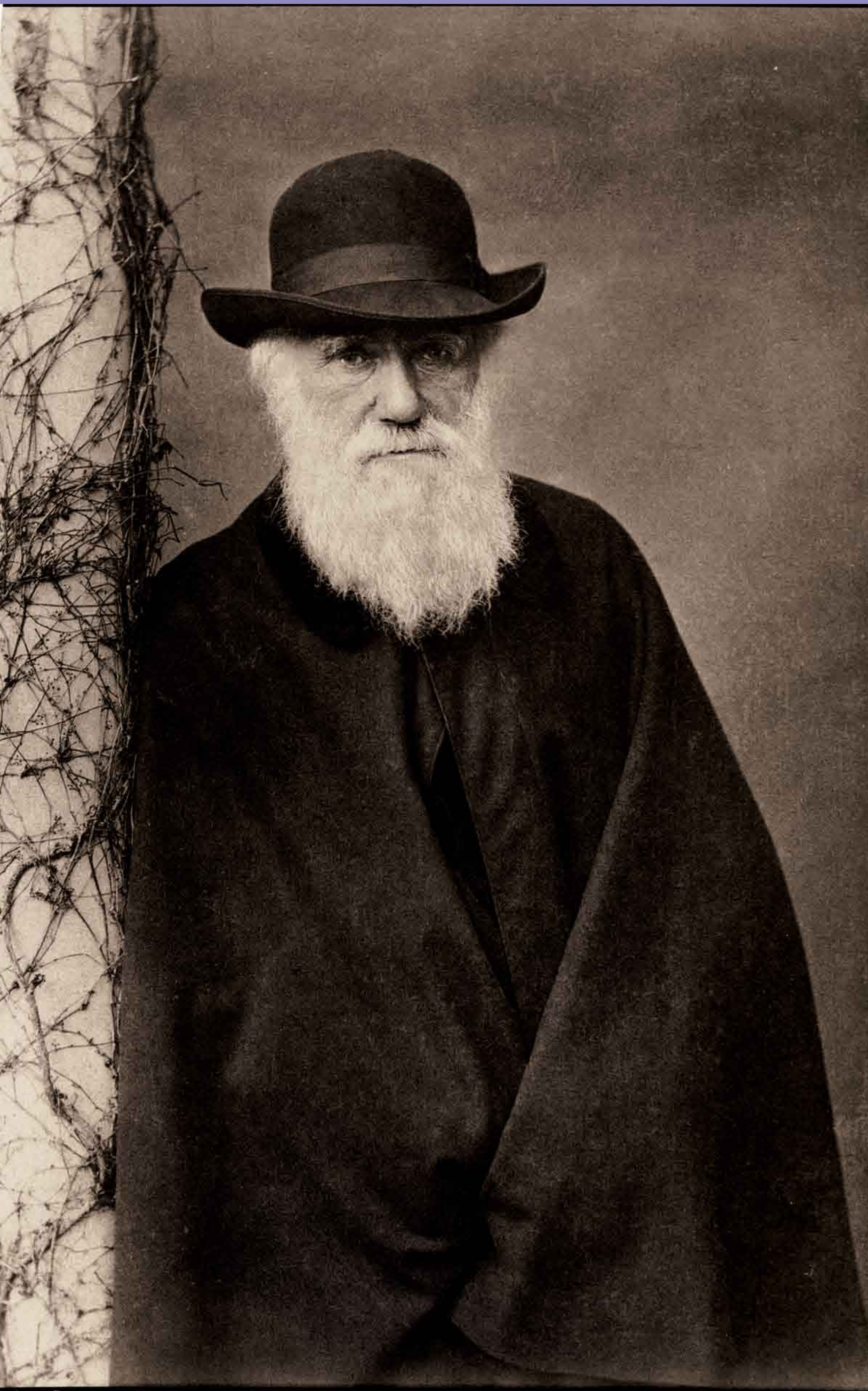


# DARWIN



## 200th ANNIVERSARY



### What difference did Darwin make?

Charles Darwin's work was an enormous advancement to the development of science.

His book, *On the Origin of Species*, was published in 1859.

### NATURAL HISTORY

Darwin studied the history of nature: how and why nature changes.

Darwin made a huge difference to the way we answer fundamental questions, such as:

Who are we?

Where did we come from?

Why do we exist?



#### WHAT DO YOU THINK?

Do you know any answers to these questions?  
Do you have more questions like these?

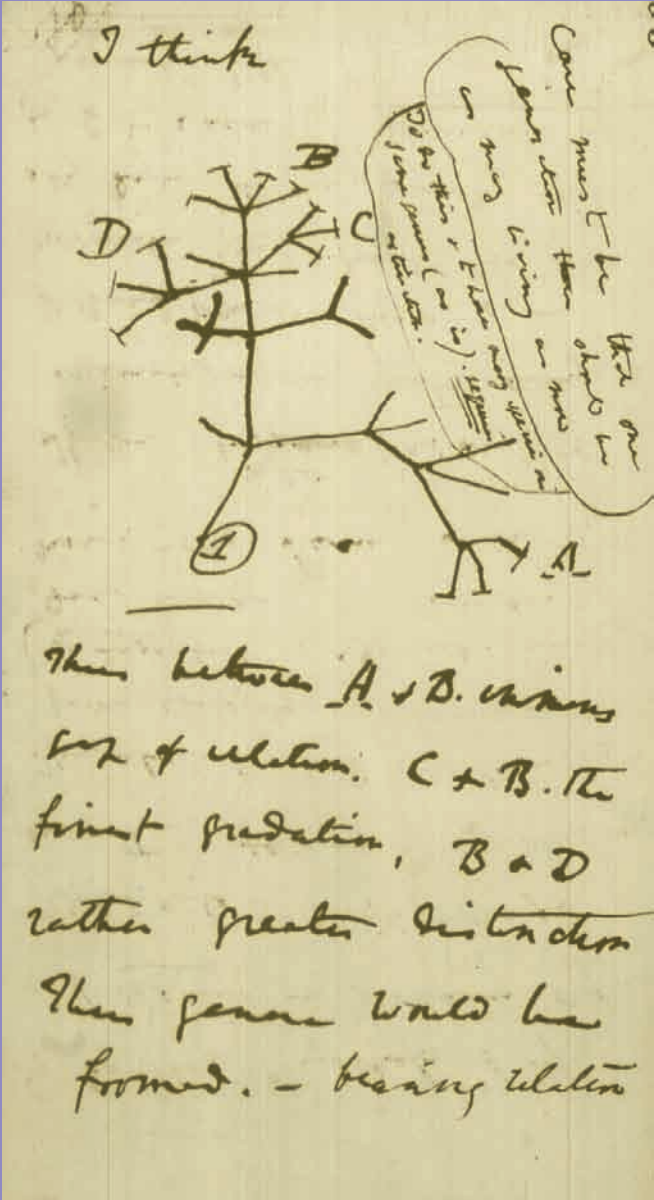
Our answers to these questions affect how we live and act.



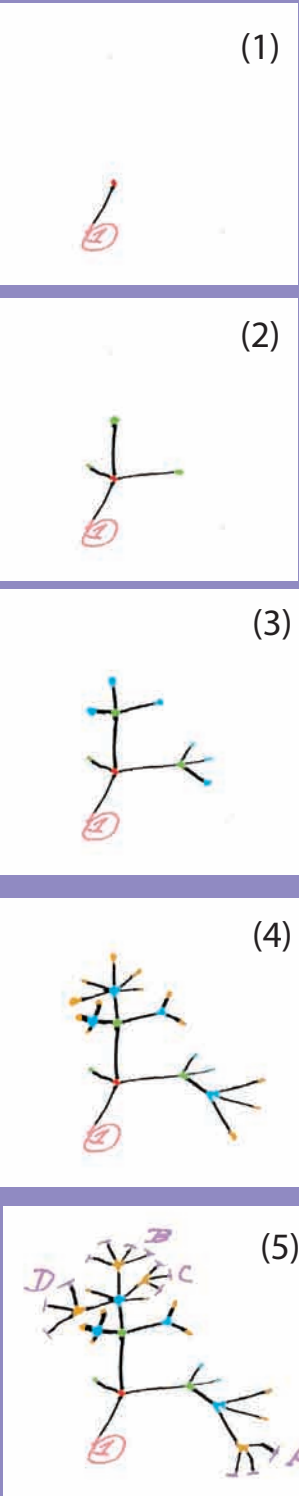
Darwin asked:  
What are species and where do species come from?

He used science to find the answer:  
“Each new species arises by descending, with modification, from an ancestral species.”

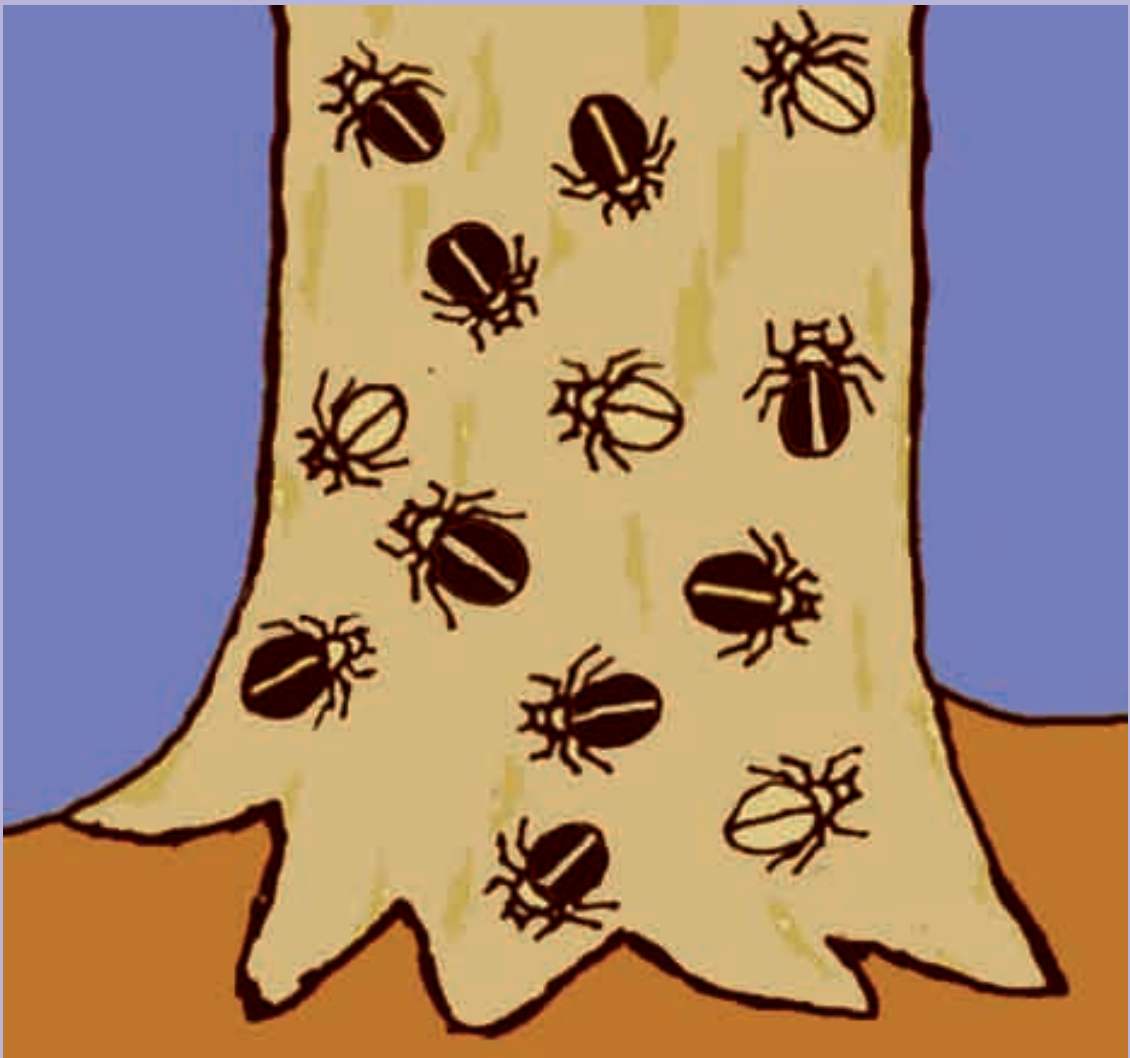
In other words, species **evolve**.



This is a page Darwin wrote during the time when he was formulating his ideas about the origin of species. The diagram shows the relationships between evolving species. An ancestral species (1) gives rise to another species, which gives rise to a number of other species (2), and so on (3), (4), (5). However, as new species arise, many species become extinct - keeping the number of species nearly constant over short periods of time. In the diagram, all the species without bars have become extinct. Thus, in (4) there are 13 species present (shown in orange), and in (5) there are still 13 species (shown in purple) - because a number of species became extinct. Of the contemporary species some are more closely related than others. For example, B and C are more closely related than A and B. Perhaps species B and C belong to one genera and species A belongs to another genera.



# EVOLUTION

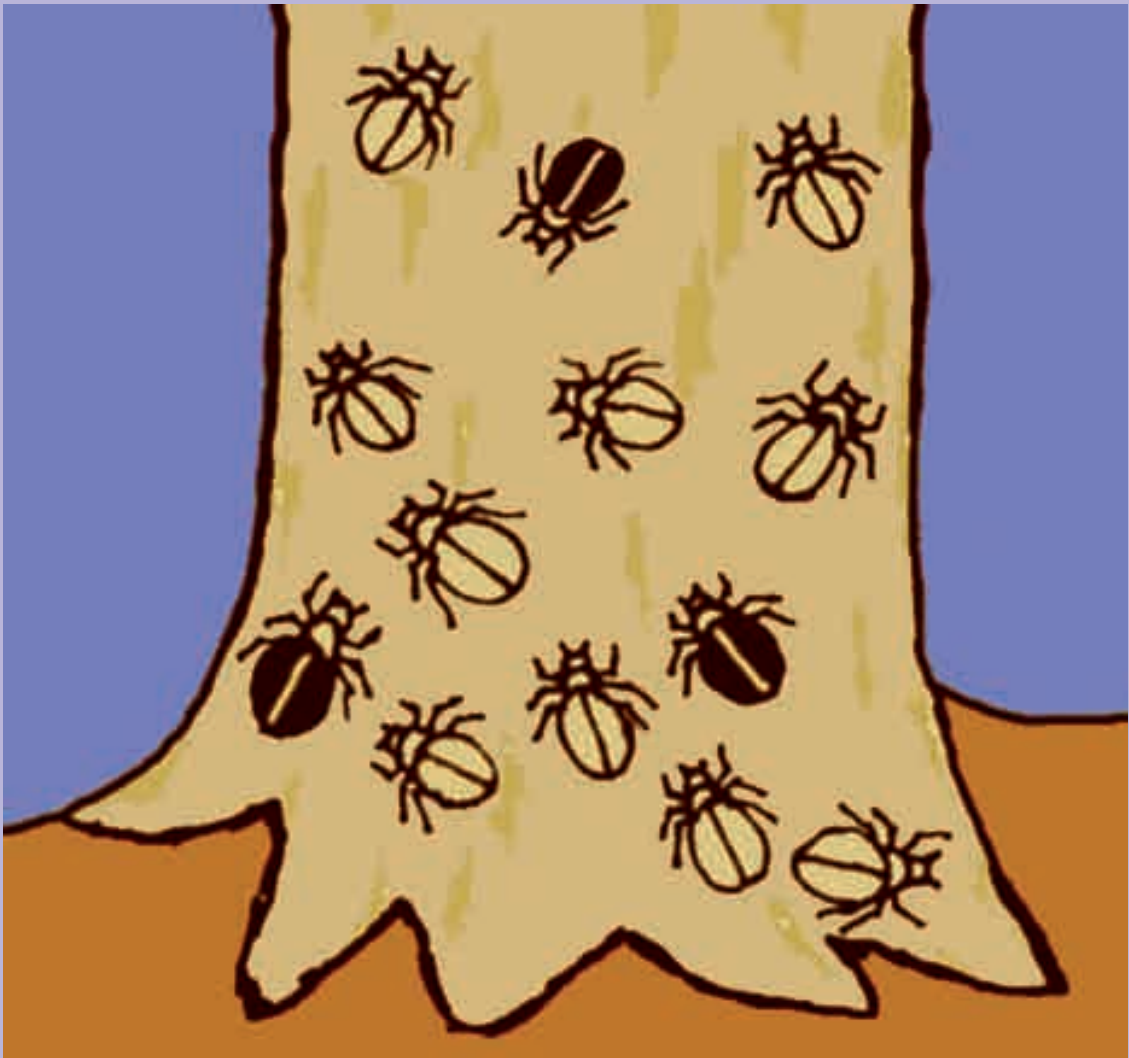


A population of beetles with variation in colour - some are dark, some are light. Their colour depends on their parents.

An **individual** organism does not evolve. **Populations** of organisms evolve.

A population is a group of organisms of the same species living in the same place at the same time.

A beetle's colour depends on the genes it inherits from its parents.



After a number of generations, the population has evolved.

How is the population different?

A species can be defined as a population of organisms that interbreeds, producing fertile offspring. Over time, populations change. (They "descend, with modification".) This change is called evolution.

If the change is so great that the resulting population can no longer interbreed with the original population, we say that a new species has evolved.

Darwin's work helps us understand how life has evolved.

Now we are even beginning to understand how life evolved from non-life in the first place.

Since Darwin, it has become more and more clear that reality is constantly changing and can be understood in terms of physical processes.



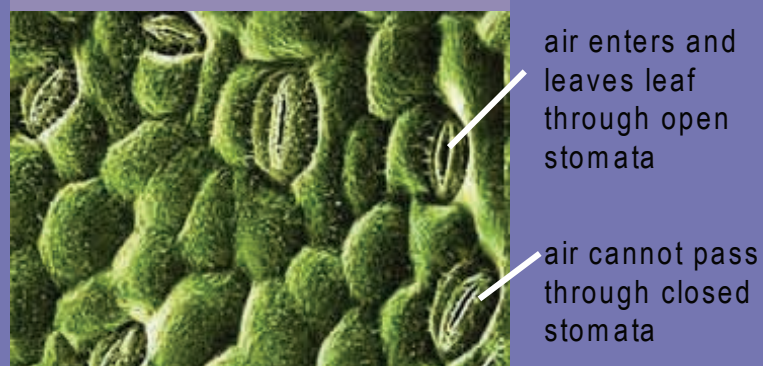
# EVOLUTION IS A KIND OF CHANGE

All change is not evolution.  
There are many different kinds of change:

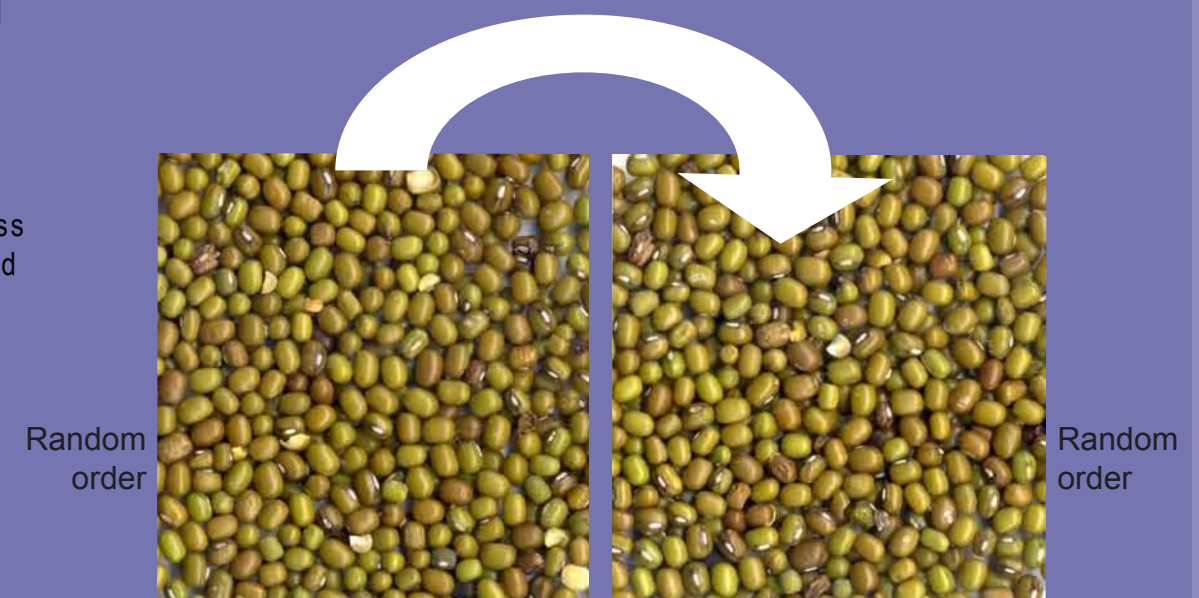
Cyclical changes - like the seasonal changes from year to year



Oscillating changes (back and forth between two states) - like a stomata opening and closing



Random changes - for example, taking a heap of seeds that are randomly dispersed, and randomly mixing up the heap.

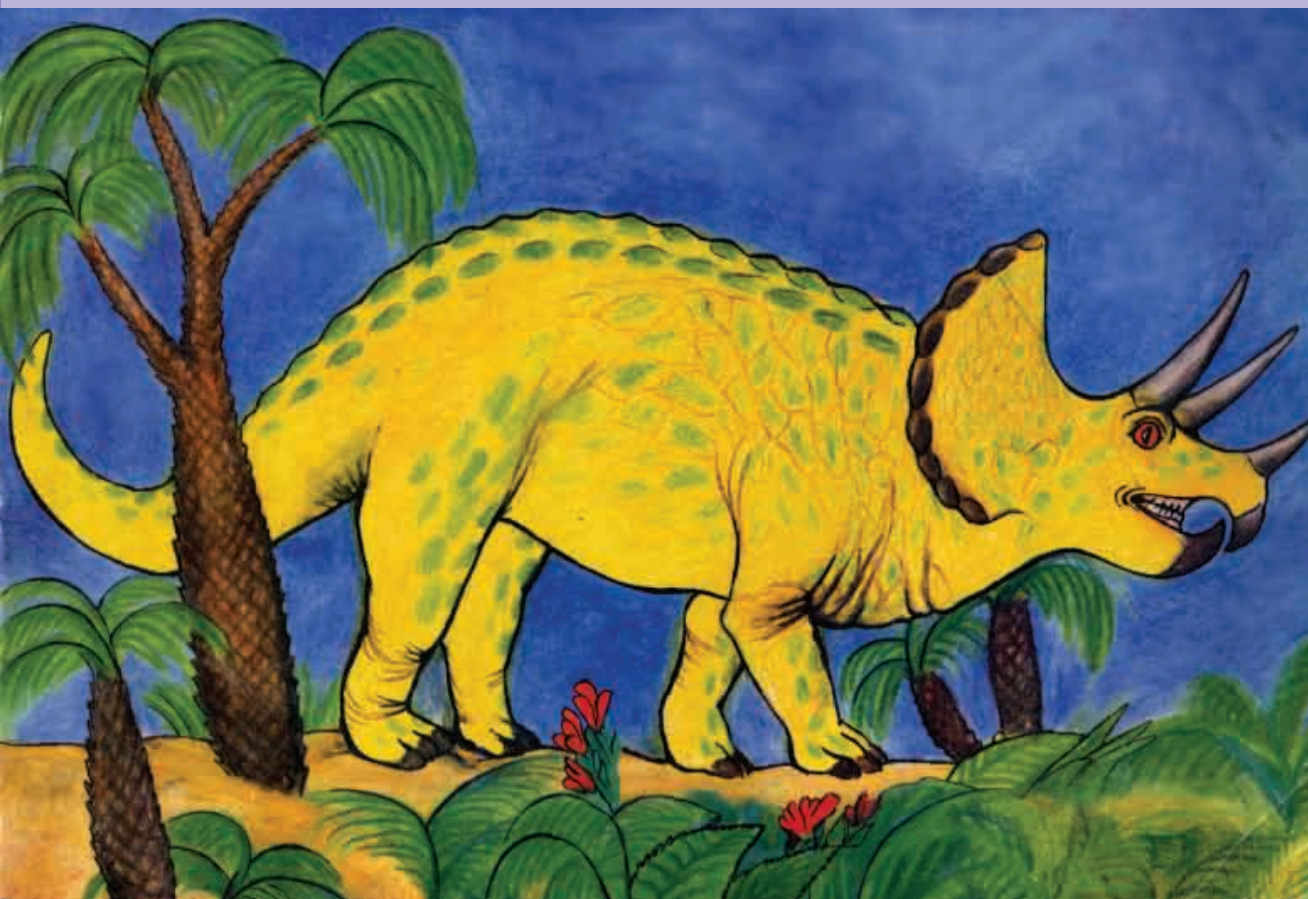


These kinds of changes are not like evolutionary changes.

In some sense, nothing changes...

Evolution can never go backwards or repeat itself.  
In other words, evolution is a change with a component of directionality.

For example: All dinosaurs became extinct 65 million years ago, and they never appeared again.



After dinosaurs became extinct, was the world just like it had been before dinosaurs evolved?

No. Dinosaurs could not have existed without affecting and being affected by other living and non-living things in their environment. Dinosaurs changed the earth. Thus it is not surprising that after becoming extinct, dinosaurs did not evolve again - different forms of life evolved instead.



The world can never go back to be just like what it was in the past.

WHAT DO YOU THINK?

If all life on earth was suddenly wiped out, could the earth possibly be the same as it was before life evolved?

List some ways that life has irreversibly changed the earth. Has your own life changed the world?

Nature depends on natural history:  
The nature of life at any moment depends on its past.



# EVERYTHING CHANGES...



Even rocks change...

Layers of rock and sediment get piled on top of each other...

Mountains slowly rise in great upheavals...

Mountains get worn away by rain, ice, wind, and chemical reactions...

Older layers of rock lie under newer layers. Scientists look at layers of rock to learn about the past.

## NOT ALL ROCKS ARE ANCIENT



New rocks are formed everyday as volcanic lava cools.

You can make a rock in a few days:

Dissolve a few spoons of salt ( $\text{NaCl}$ ) in a small amount of water. Leave the salt water on a plate for a few days. Rock crystals will form.



This happens in nature also. For example, in these salt flats in Death Valley, USA.



The naturally occurring rock made of  $\text{NaCl}$  is called halite.

WHAT DO YOU THINK?  
Can you think of anything that does not change?



# WE FIND TRACES OF ANCIENT LIFE IN ROCKS



These fossils resemble various organisms. But they are made of stone. What kinds of fossils do you see in these layers of rock?



Darwin noticed fossils of marine creatures high in the mountains of South America. He asked, "How did they get there?"

Darwin was not the first one to make such observations. Here is an example from ancient China:

"In the high mountains, I have seen shells. They are embedded in rocks. The rocks must have been earthy materials in days of old, and the shells must have lived in water. The low places are now lifted high, and the soft material turned to hard stone."

-Chu-Hsi (China, 1200 CE)

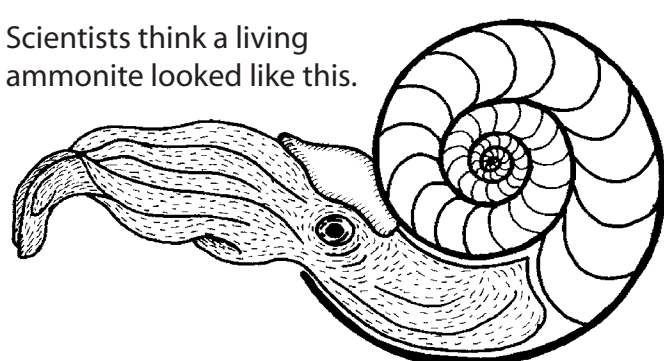
How do you think fossils of sea life got to be so high in the mountains?

## FOSSILS: traces of ancient organisms



Some 150 million years ago this was a living ammonite - now it is a fossil.

Scientists think a living ammonite looked like this.



This is a stone, but it has traces of ancient leaves in it.



# The earth was very different in the past

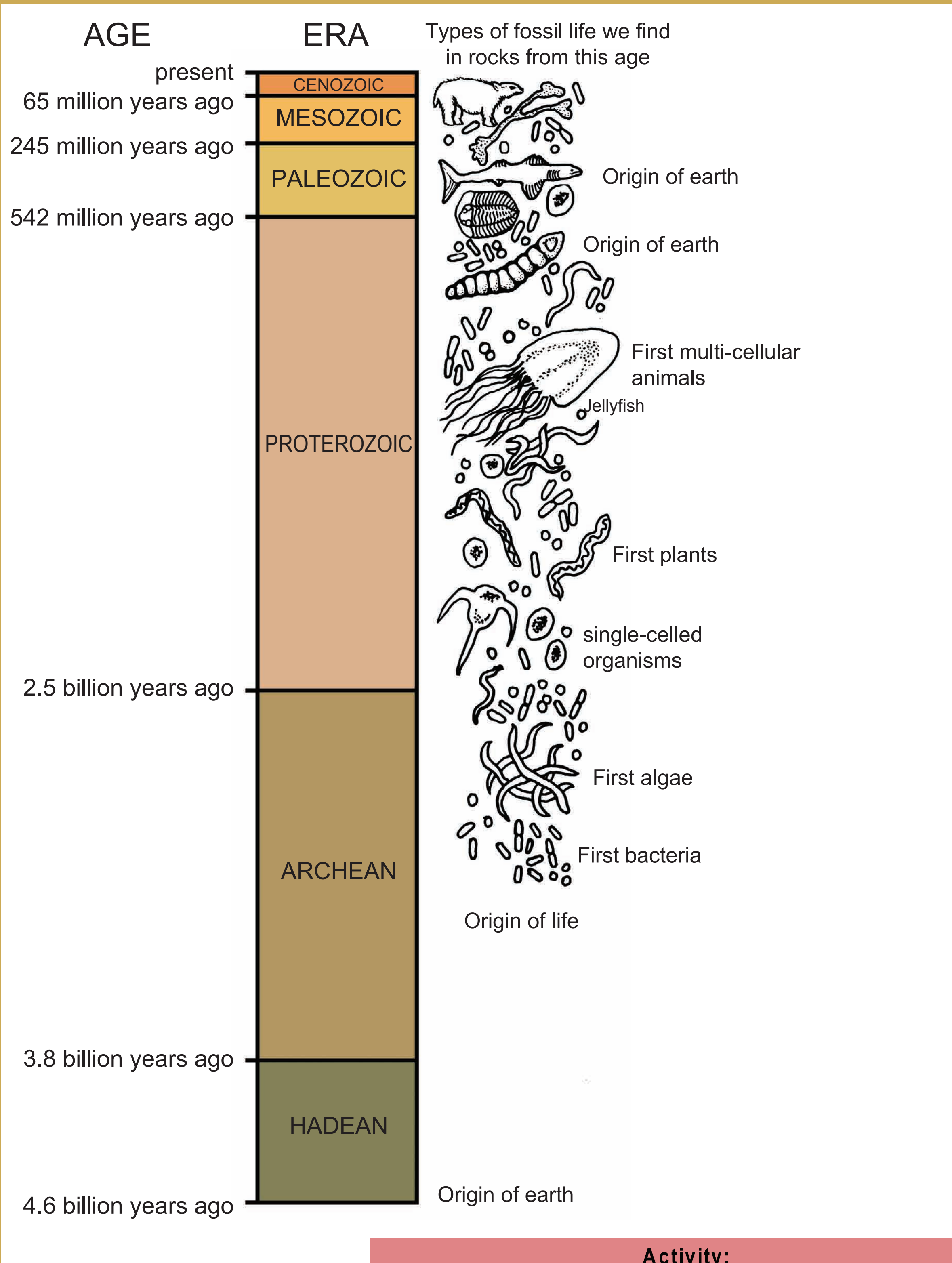
There was a time when there were no people.

There was a time when there were no animals.

There was a time when there were no plants.

There was a time when there were no microorganisms.

There was a time when there was no life at all.



## How do we know this?

We can measure the ages of the different layers of rock in which we find fossils. For example, we find fossils of animals only in layers of rock that are more recent than 1 billion years old. We find fossils of plants only in lower layers that are more recent than 2 billion years old... and if we dig down deep enough, we find layers without any fossils at all.

## Activity:

Use a long piece of rope (either 10 metres or 50 metres long) to get a better understanding of the long time scale for evolution of life on earth

Event	Millions of years ago (approximate)	Distance (on a 10 m long rope)	Distance (on a 50 m long rope)
First modern humans	1.8	3.6 mm	1.8 cm
Dinosaurs become extinct	65	13 cm	65 cm
First dinosaurs	248	50 cm	2.5 m
First reptiles	390	78 cm	3.9 m
First amphibians and insects	417	83 cm	4.2 m
First vertebrates (fish)	443	88 cm	4.4 m
First land plants	490	0.98 m	4.9 m
First multi-cellular animals	800	1.6 m	8 m
First eukaryotic cells	2,100	4 m	20 m
Oxygen begins accumulating	2,700	5.4 m	27 m
Origin of life	3,500	7 m	35 m
Origin of earth	4,700	9.4 m	47 m



By studying fossils, scientists have found out that in the past there were different forms of life that are now extinct. Each new thing is replaced by a newer thing...



How do we know?  
Trilobite fossils are found only in layers of rock that are between 540 and 250 million years old. Scientists use many different methods to date fossils, such as stratigraphy, paleomagnetism, measuring radioactive decay, volcanic ash correlation, ESR, and thermoluminescence..

After this trilobite died, it was buried in silt and mud. The organic material it was made of was slowly replaced by minerals. After millions of years, it turned to stone.

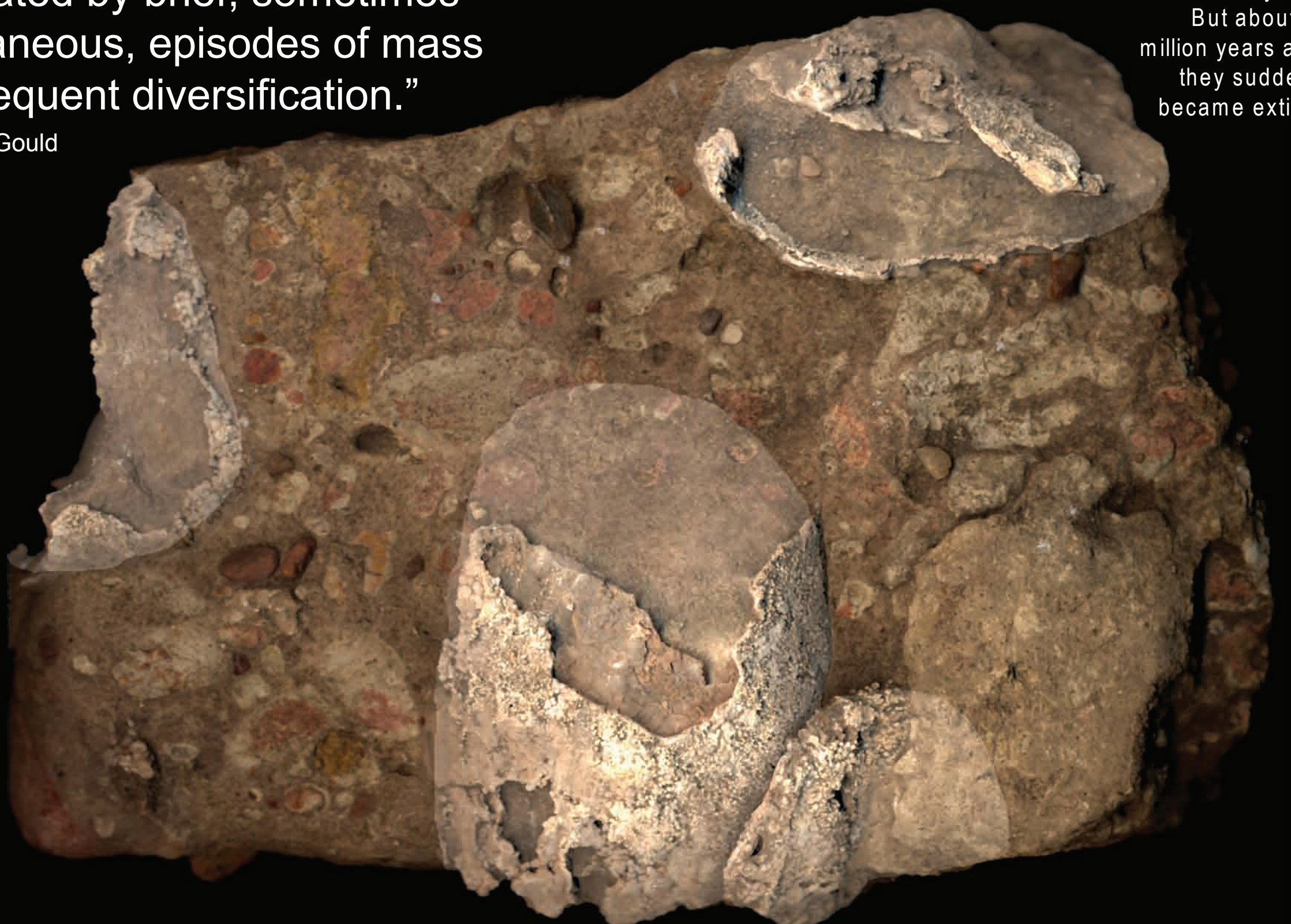
Probably more than 99.9% of the species that ever lived on earth are now extinct..

“The history of life is not a continuum of development, but a record punctuated by brief, sometimes geologically instantaneous, episodes of mass extinction and subsequent diversification.”

-Stephen Jay Gould

In other words, natural history shows that evolution is not always steady and continuous. Instead we see long stretches of slow change punctuated by periods of sudden, radical change.

Dinosaurs thrived on earth for about 250 million years. But about 65 million years ago, they suddenly became extinct.



A dinosaur egg nest found in Gujarat.



# Darwin found more evidence that life evolves by studying the GEOGRAPHIC DISTRIBUTION OF SPECIES

He compared Cape Verde and Galapagos Islands



Cape Verde Islands are close to Africa

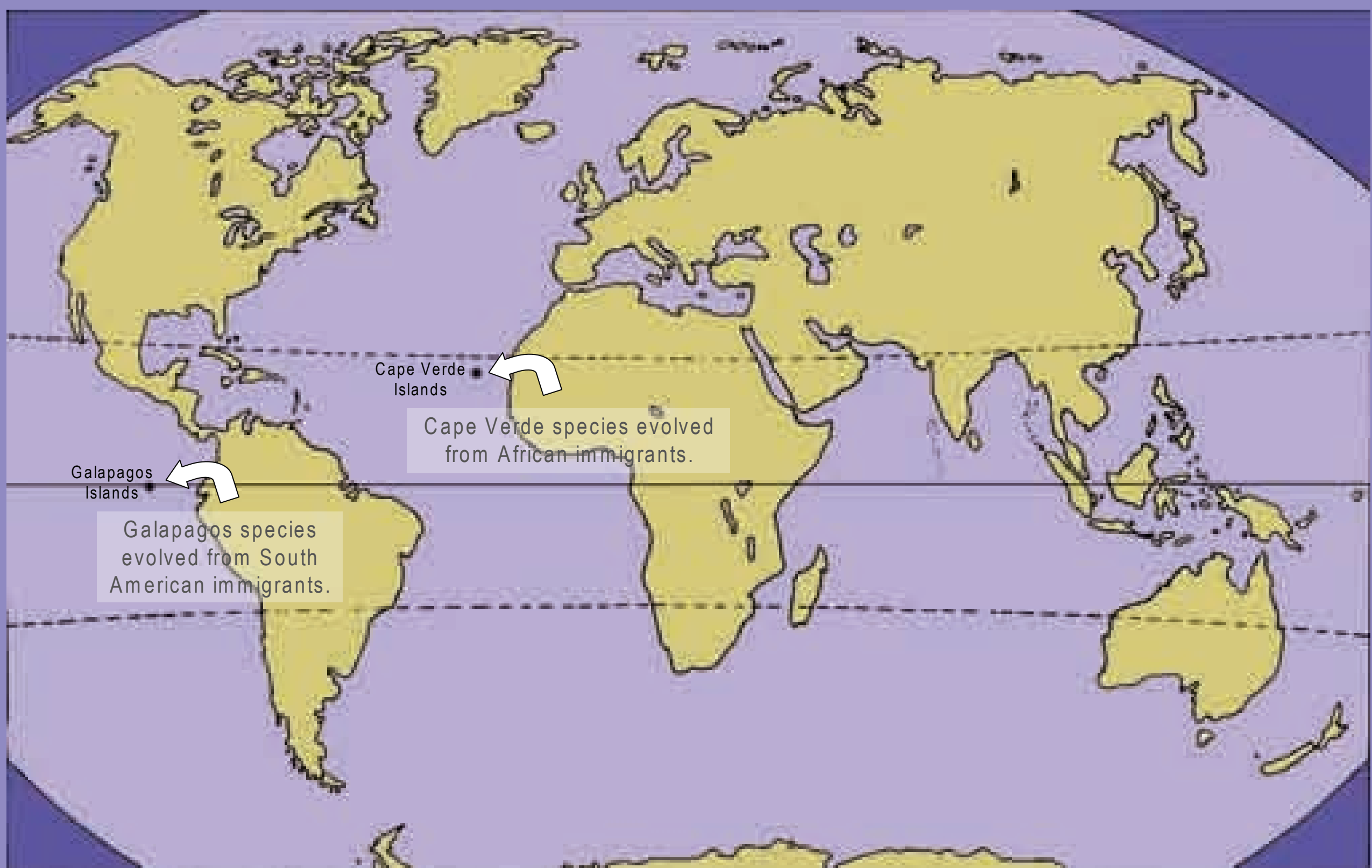


Galapagos Islands are close to South America

Darwin observed that both are volcanic islands with a warm, arid climate.  
Both are very different from their closest continent.

So he asked:

**Why aren't the species of Cape Verde similar to the species of Galapagos?**



Some Cape Verde species



Some Galapagos species



# WHERE DID WE COME FROM?

## Answers from Ancient India:

### Creation Myths

Every culture has its own creation myths. One example is shown in this picture.



### Doubts about Creation Myths

Then even nothingness was not, nor existence.  
There was no air then, nor the heavens beyond it.  
Who covered it? Where was it? In whose keeping?...  
Who really knows and who here can say  
Whence it all came and how creation happened?  
The gods themselves are later than creation -  
So who knows truly whence it has arisen?

-Rig Veda

### Beliefs in Reincarnation

## संसार

All animals (and plants, and even water, dust and air, some say) are interlinked and live under the same law.

All life passes through innumerable changes. The souls of each individual pass to a new abode, reincarnated as another form of life...



WHAT DO YOU THINK?  
Do you know any stories about where we came from?

### Sceptics

(Pyrronists)

There is no possibility of any certain knowledge

Speculation on first causes is a futile waste of time  
- Buddha

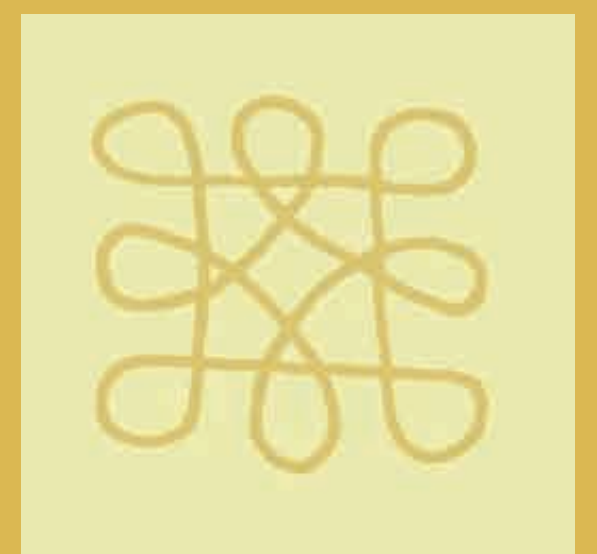


### Materialist Ideas

Early South Asian Materialism  
(7th and 6th centuries BCE)

There is no soul  
There is only matter  
The universe is made of atoms

The universe was not created by any external god - it developed as a process of internal evolution, or 'ripening' - *parinaama*.



These ancient ideas on creation and evolution are different from the present-day understanding that is based on science.



# WHAT IS SCIENCE?



Science is not just a list of 'facts'.

Science is a process of:

- questioning
- hypothesizing and model building
- observing and measuring
- testing and retesting
- finding evidence
- analysing
- modifying conclusions
- requestioning

Note that there is considerable variation in the method: the order is not fixed, and not all of these processes are always included.

Of course, science also requires reasoning - especially inductive reasoning, analogical reasoning, coherence, parsimony, precise word definitions, a communication network, etc.

Find out more about science and what all these words mean...

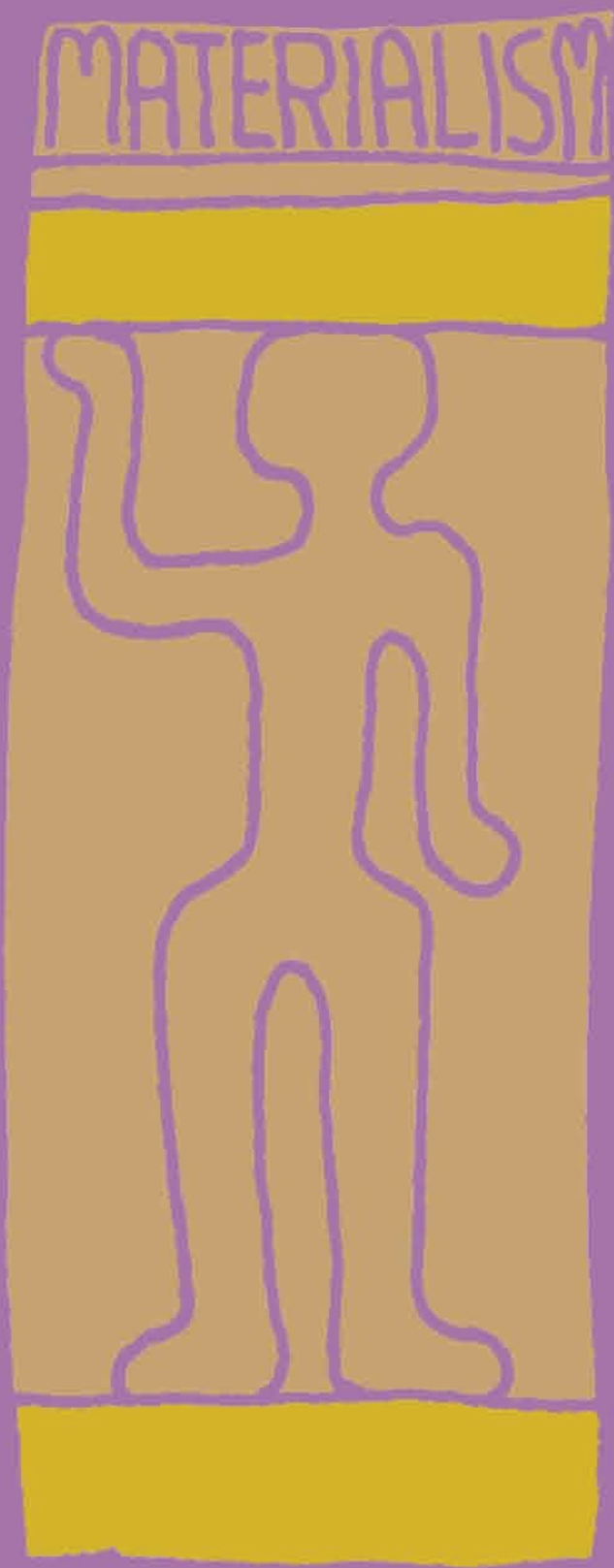
<http://plato.stanford.edu/>



# Our thinking about evolution affects and is affected by our way of thinking about the world.

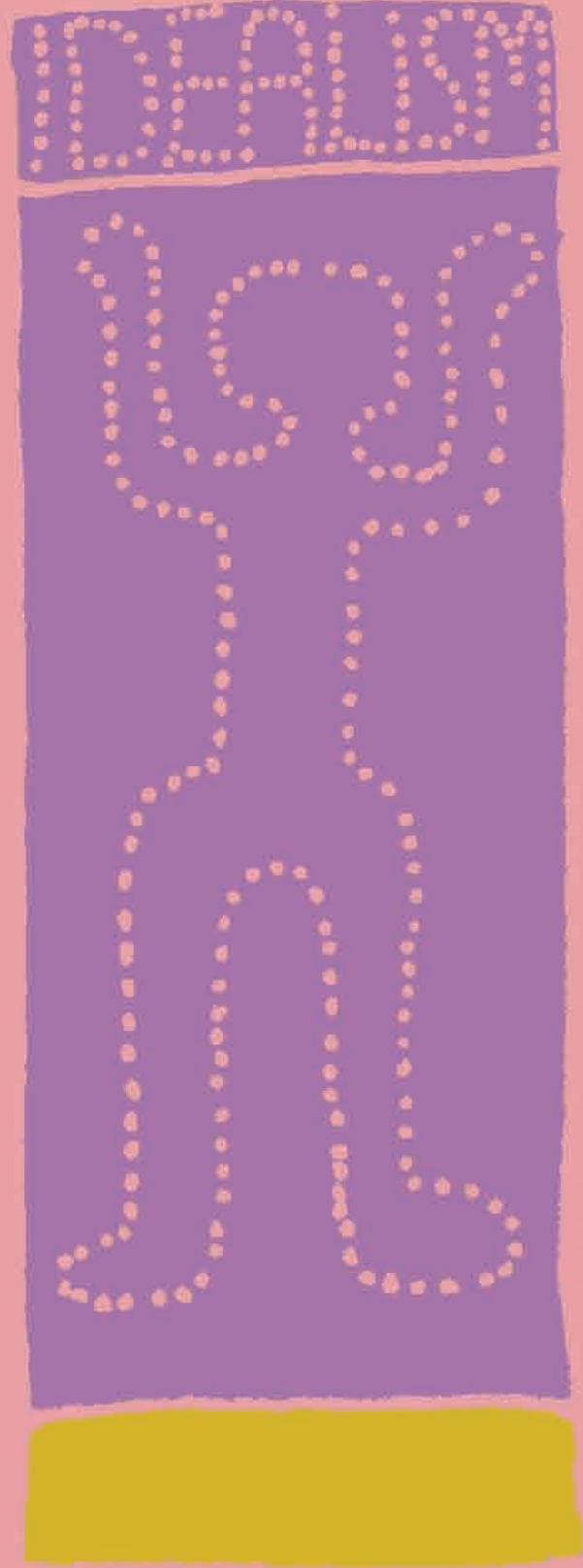
For example, let's compare two ways of thinking: materialism and idealism

How might evolution be seen differently by a materialist and a dualist?

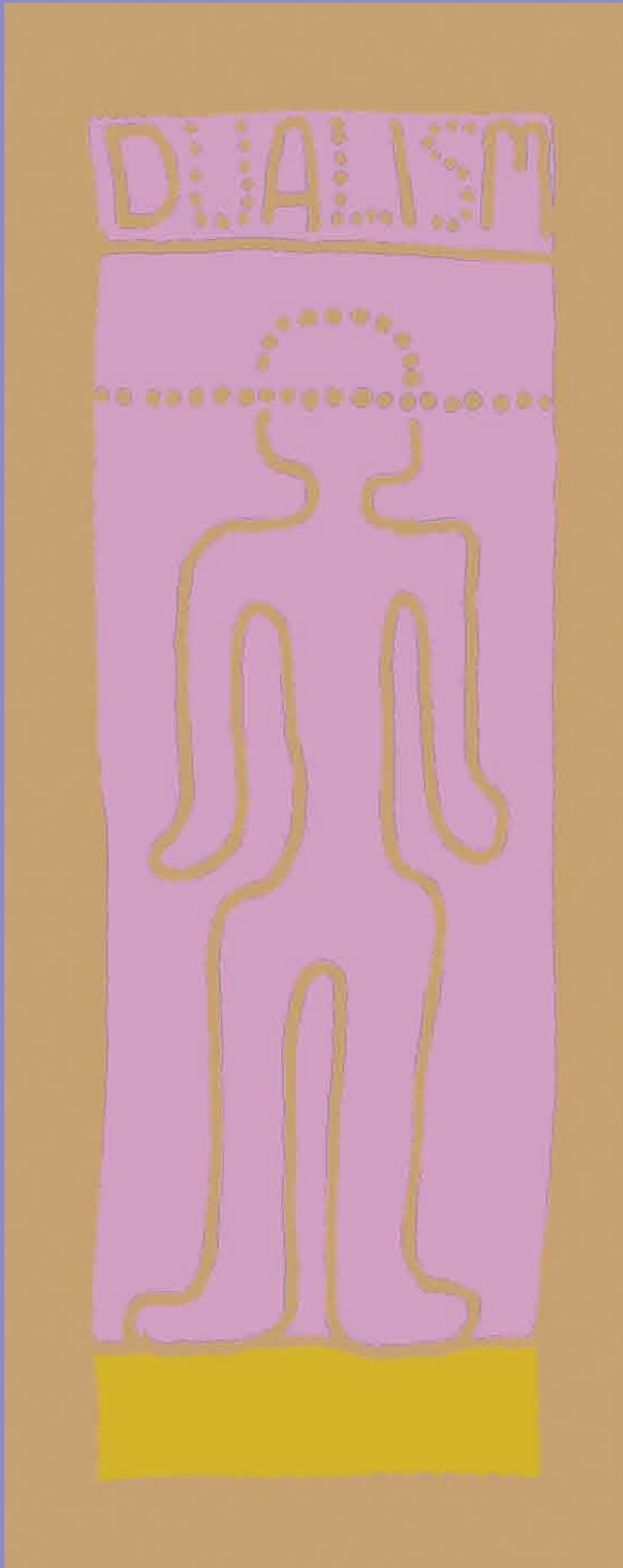


According to MATERIALISM, 'matter' is basic:  
Ideas cannot exist without matter.  
  
Mental processes are physical processes of the brain  
  
Life could be created and evolve by itself, without any design, purpose, or 'spirit' acting as a guiding force

According to IDEALISM, 'ideas' are basic:  
Matter is derivative of mind.  
  
Ultimately, matter is not real.  
  
Life could be created and evolve because some 'spirit' makes it happen.



There is also another way of thinking:



According to DUALISM, there are two worlds:  
1. The world of physical states  
2. The world of mental states (ideas)  
  
A person is a physical body + a mind (or soul)  
  
Life could be created and evolve in the physical world.



According to a dualistic way of thinking, the two worlds should be kept separate:  
1. Science deals with facts and theories  
2. Religion deals with ethics and ultimate meaning

But, how can they be kept separate?

But, if these states are separate, how do they interact with each other?

And they must interact with each other. For example, how does the mind tell the body to raise a hand?

So doesn't this necessary interaction prove that there are not two separate states after all?

A person who is a dualist might use science to understand evolution and religion to find correct moral behaviour.





# Evolution may contradict religious authority

Using a scientific method, we see that evolution occurs.

Some religions say that evolution does not occur.

We can change a scientific belief by showing that it is contradictory to evidence based on observations of physical reality.

Science is based on questioning, hypothesizing, observing, testing, analysing, and rational thinking. But it is also influenced by the prevailing social structure, intuition, emotion, and the power of authority.

Can we change a religious belief by showing that it is contradictory to evidence based on observations of physical reality?

Are religious beliefs based on questioning, observing, testing, analysing, and rational thinking? Or on intuition? Emotion? Faith? Or the power of authority?

Sometimes religious authorities change their beliefs based on new scientific findings.

“Today ... new knowledge has led to the recognition of the theory of evolution as more than a hypothesis.

... it has been proven true; we always celebrate nature’s factuality, and we look forward to interesting discussions of theological implications.”

- Pope John Paul (1996)



“It seems to me (rightly or wrongly) that direct arguments against Christianity and Theism hardly have any effect on the public; and that freedom of thought will best be promoted by that gradual enlightenment of human understanding which follows the progress of science. I have therefore always avoided writing about religion and have confined myself to science.”

-Darwin (1880)

In other words, Darwin is saying that a person will not give up a religious belief just because you give a logical argument to show that it is wrong.

People will gradually change their beliefs as science progresses.

What do you think? Is it better to promote scientific thinking but avoid speaking directly against religious thinking?



# Until the 19th century, ideas on evolution remained speculative and confused...

Because of their way of thinking about the world, some people could not even consider the possibility that evolution happens.

...but change was in the air...

By the time Darwin was born in 1809, the industrial revolution was occurring in the west and capitalism was in full swing. Social relations were changing. Thus, people there were more apt to accept that change is inherent to life.

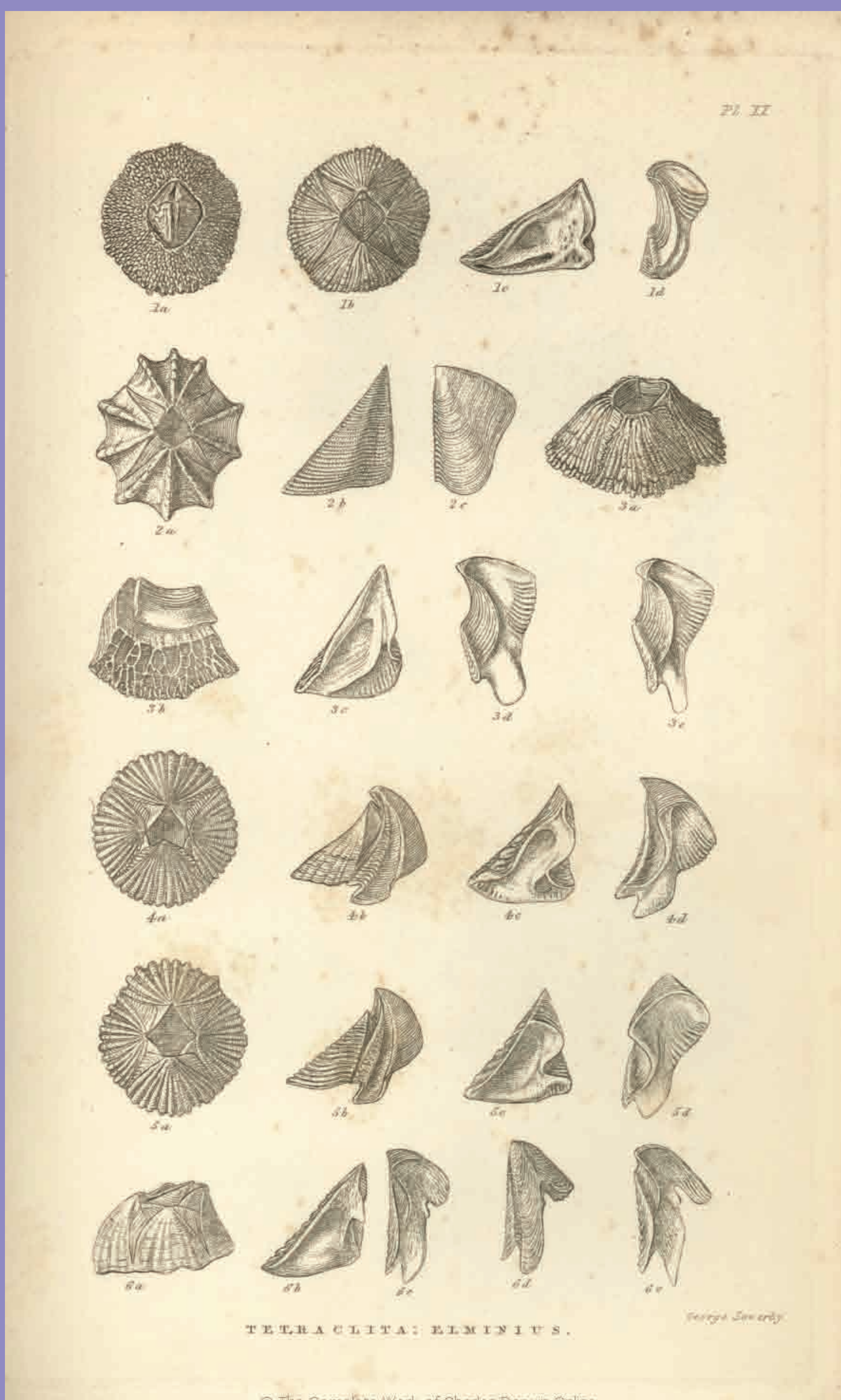
The Enlightenment and the French Revolution led Europeans to question religious doctrines. Rational materialism became more popular.

British imperialism was at its height. Europeans were exploring and exploiting the world. This led naturalists to study the plants, animals, and geology of the world. By comparing and classifying, it became apparent that all organisms are interrelated.



## Darwin found evidence for evolution from a lifetime of studying different forms of life in different environments.

Darwin was one of the first people to consciously and systematically use the scientific method to study biology. For example, he spent eight years studying barnacles. A barnacle is a marine animal - a crustacean with a calcareous shell, such as those illustrated here. He questioned, observed, compared, and analysed - finding great variations in the structure and functioning of different kinds of barnacles. This variation is a key to understanding evolution.



The shells of barnacles can be found attached to stones on beaches.

Darwin relied on a huge network of colleagues and European intellectuals. He exchanged letters with around 2000 people over his lifetime.

His books, letters, and other work is catalogued and freely available on the internet at:

[www.darwinproject.ac.uk](http://www.darwinproject.ac.uk)

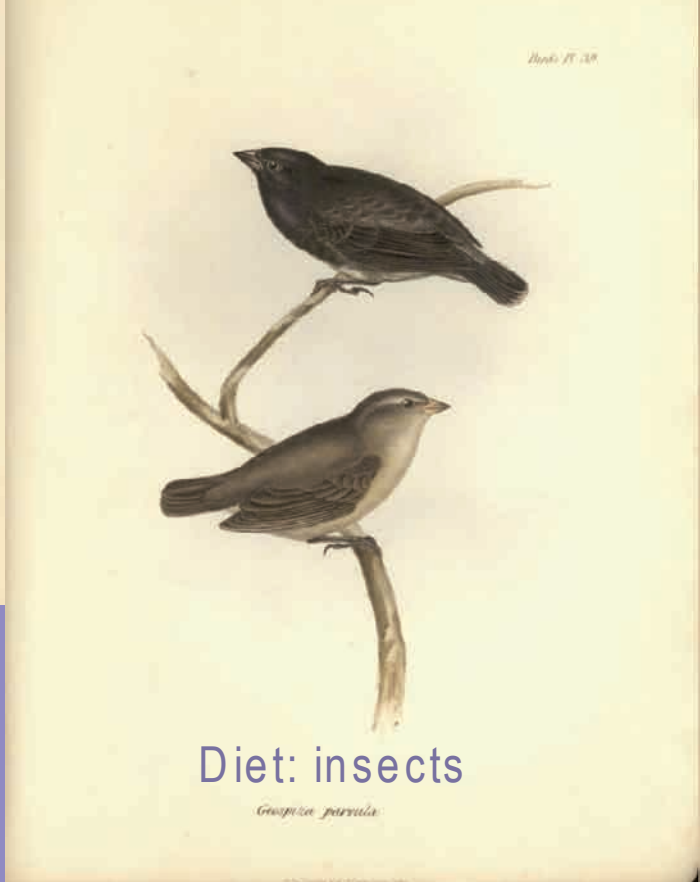
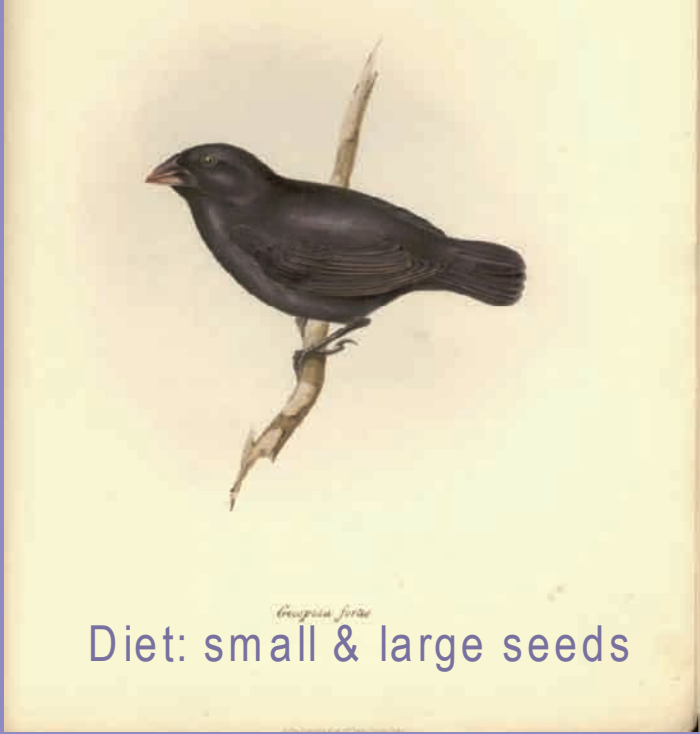
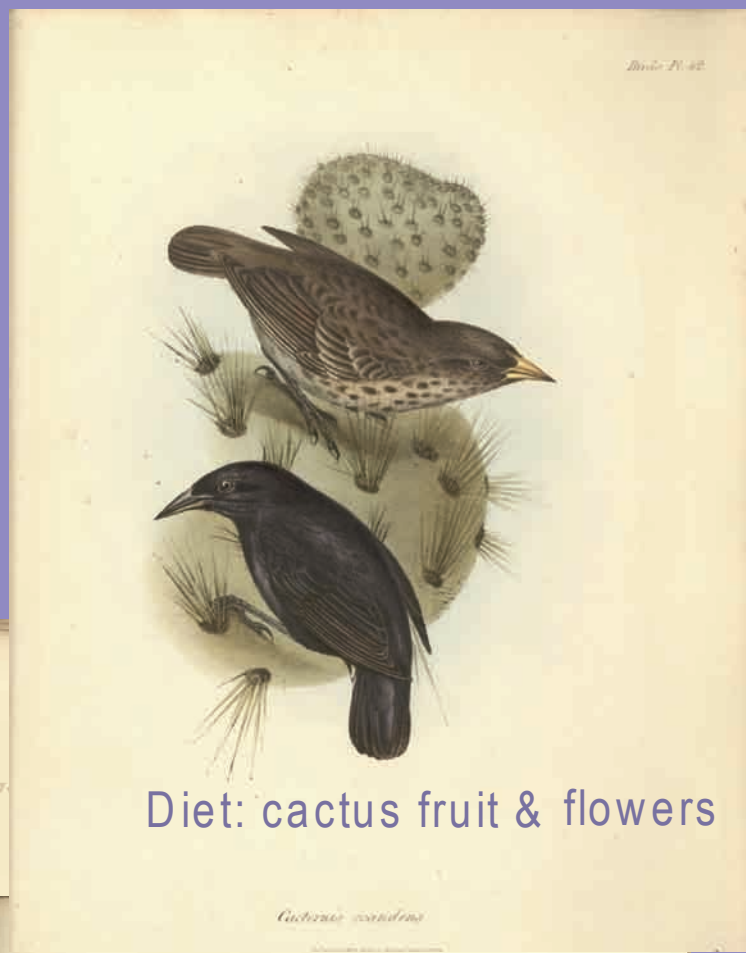
<http://darwin-online.org.uk/>



13 Upon observing life, we are struck by the amazing diversity we see. We are also struck by the similarities between different forms of life. This is called dialectics.

VARIETY

SIMILARITY



Darwin studied these finches which he collected from a number of islands of the Galapagos Archipelago. He found different species of finch on each island.

How are these finches similar to each other?  
How are they different?  
Darwin wondered: Why are they similar? ...and yet different?

Darwin concluded that the similarities between these species of finches must be because they all evolved from a common ancestral species that had come from the South American mainland. Their diversity must be because their food habits were different.

VARIETY AND SIMILARITY:  
contradictory characteristics  
inherent to life

Are individuals in a population all the same all the same?



Adult penguins go off fishing in the sea. When they return, their children have no trouble finding their parents. How do they recognise them?



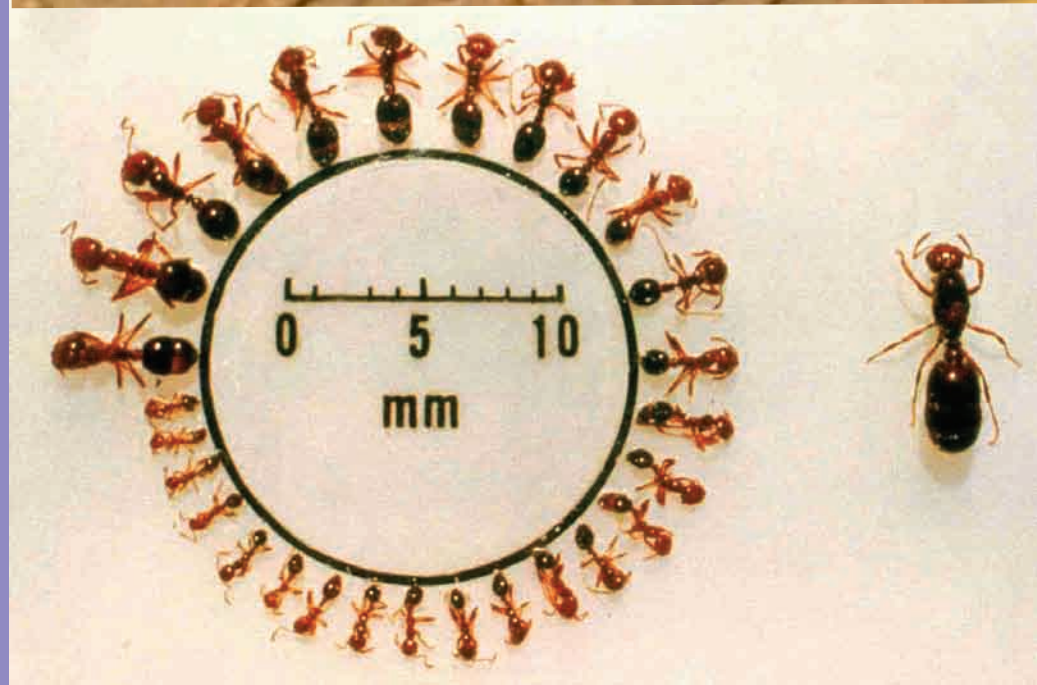
The children know the difference.



# Can you find two identical individuals in any population?



Try to find two identical animals or plants.



If you cannot find two identical trees, can you find two identical leaves? Or leaflets?

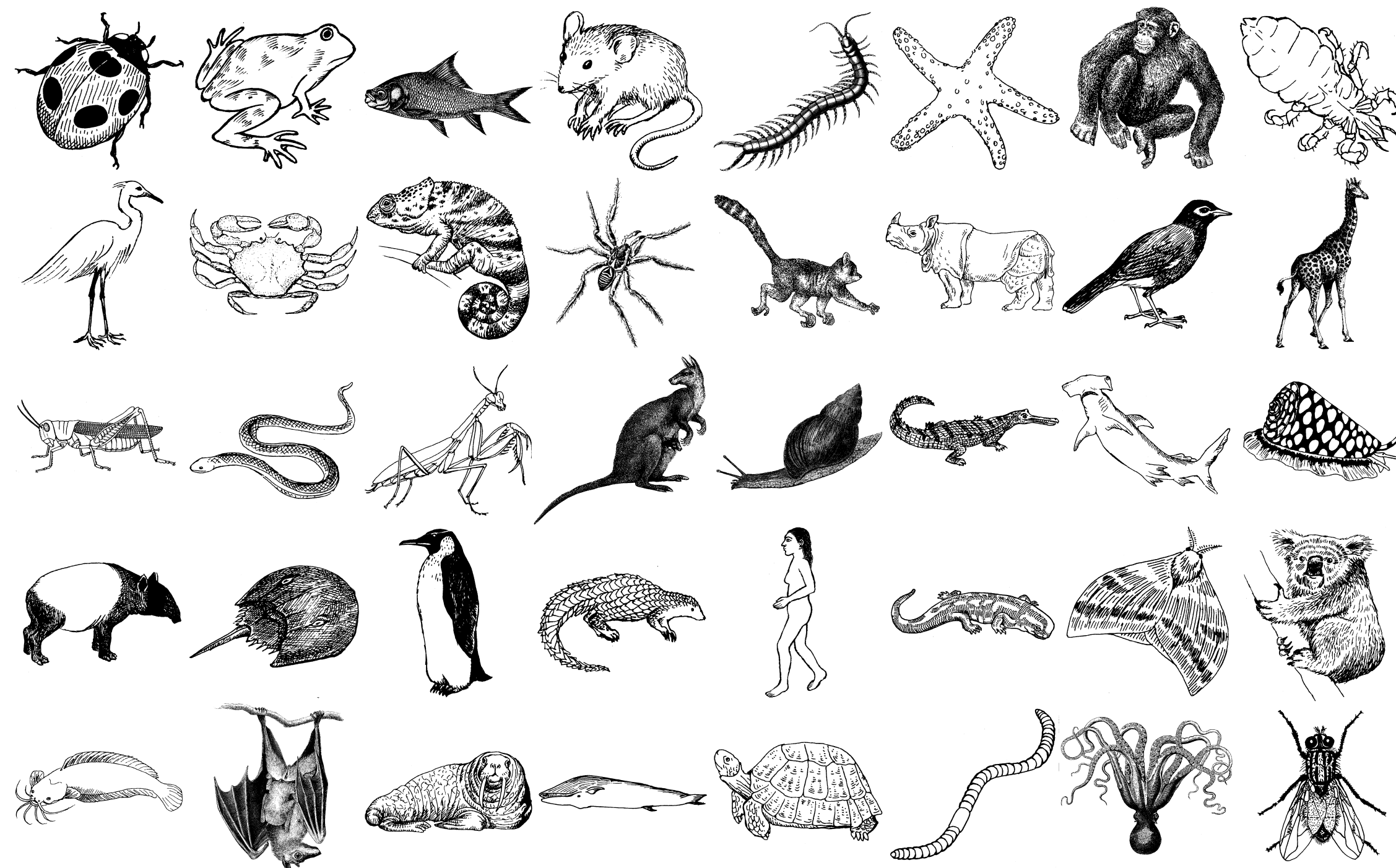


Are these gulmohar leaves identical?



# When we classify different forms of life we see evolutionary relationships.

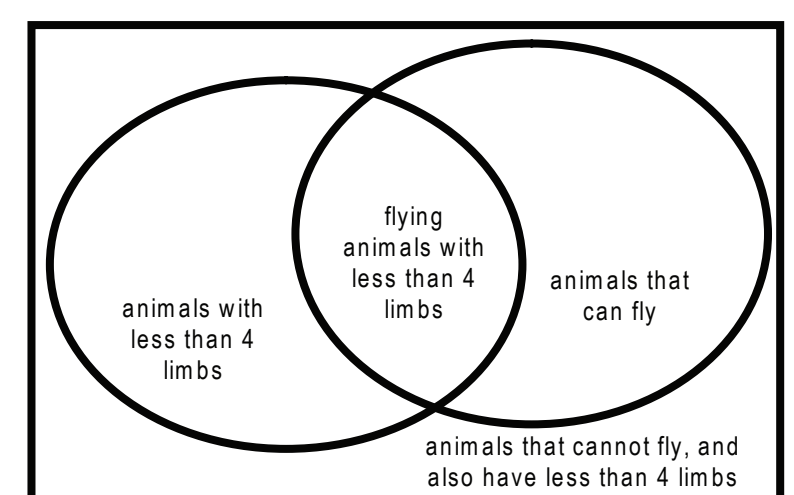
Look at these different kinds of animals. How are they similar? How are they different?



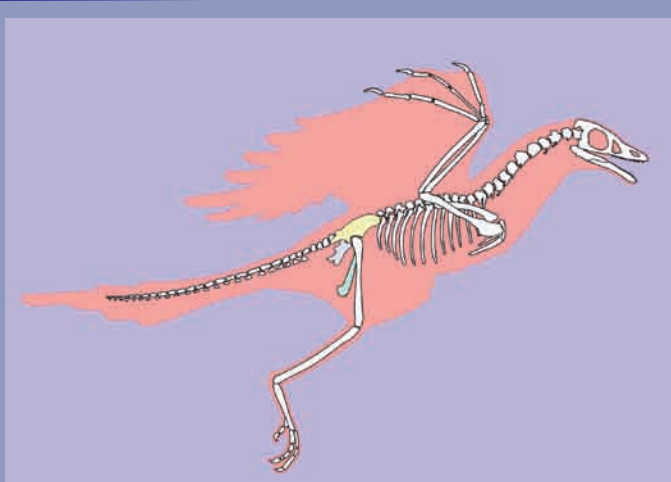
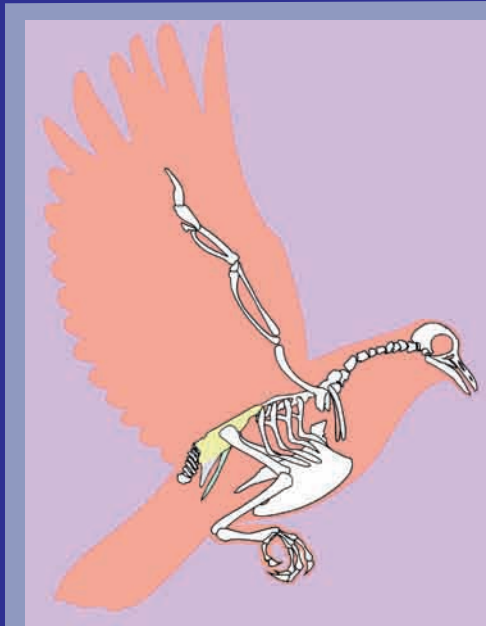
Sort these animals into groups

Define the groups on the basis of any characteristics you want, such as: size, shape, colour, habitat, behaviour, etc.

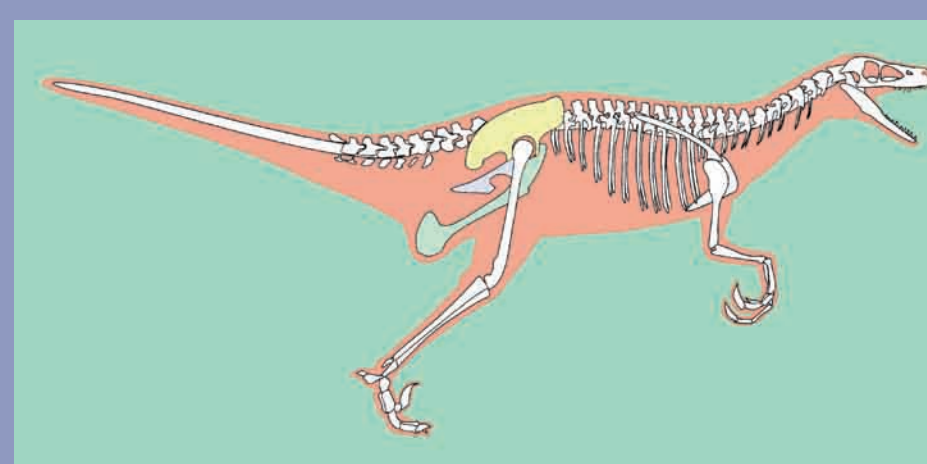
Make Venn diagrams like the one shown below.



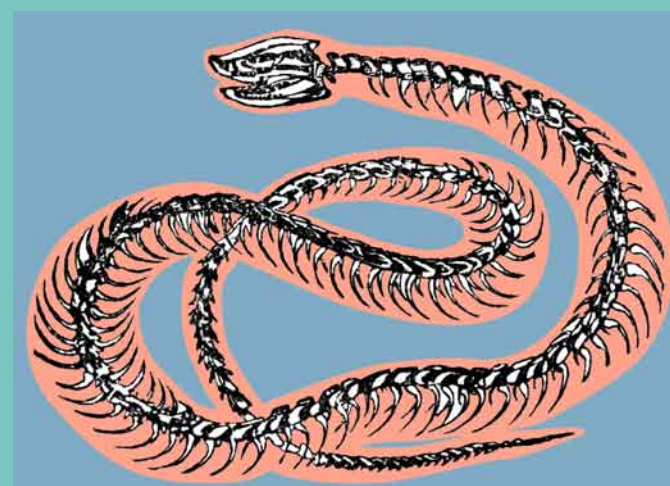
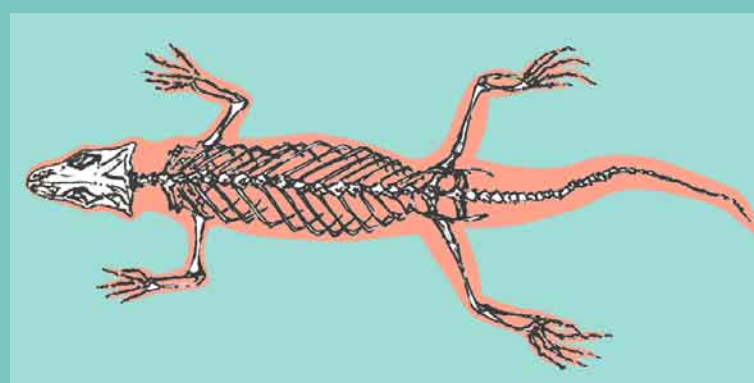
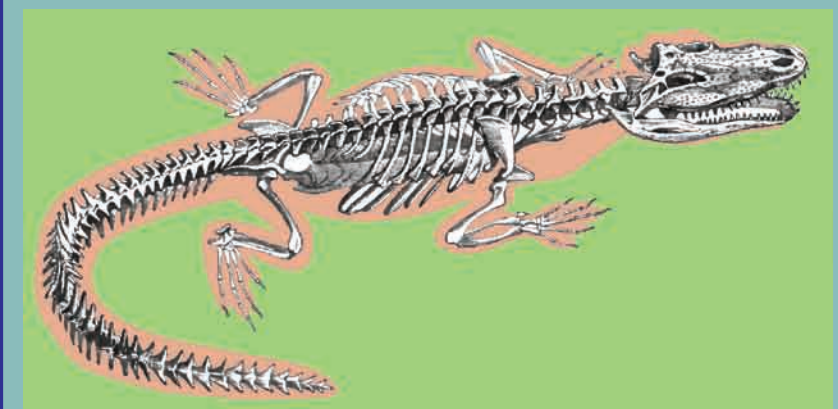
## What do we learn from classification?



Birds are related to dinosaurs.



Birds and dinosaurs are related to crocodiles.

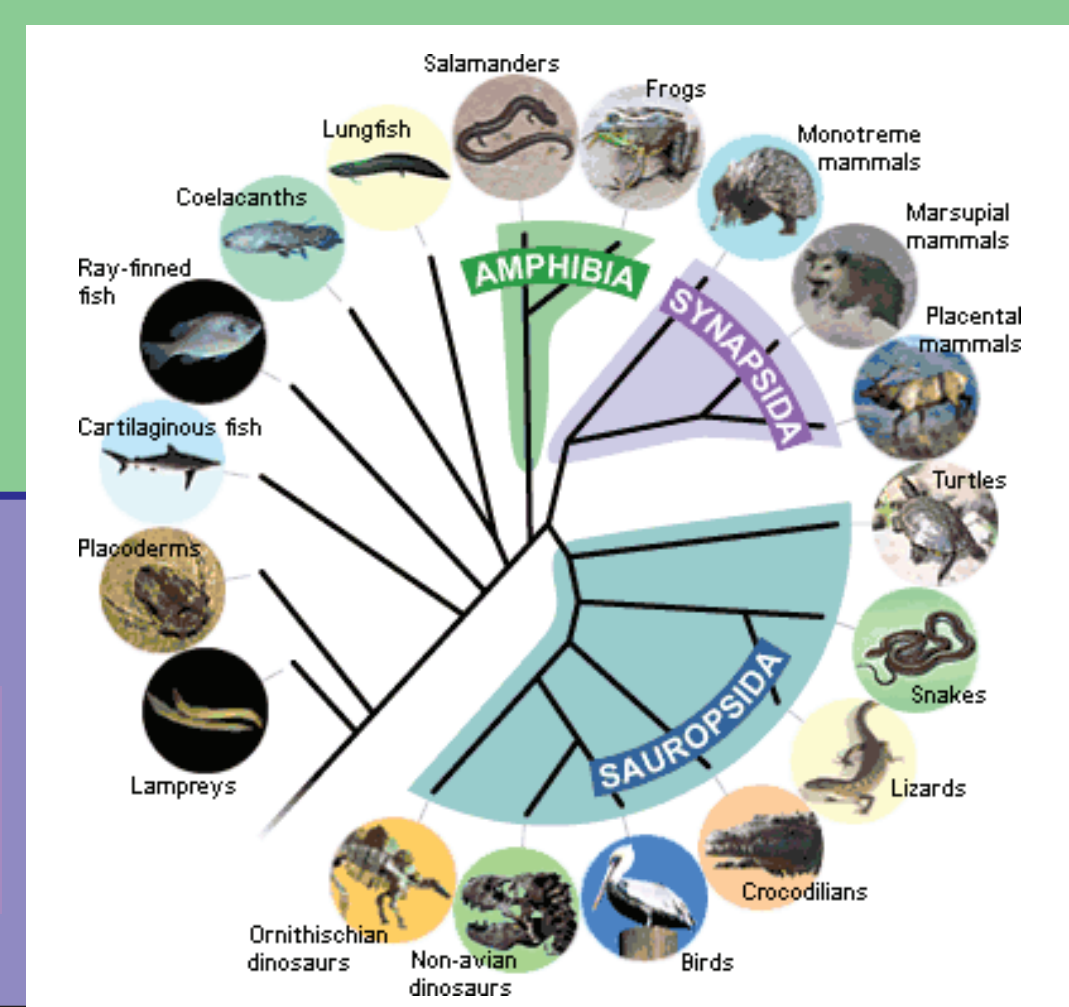


Lizards are related to snakes.

Birds, dinosaurs, and crocodiles are related to lizards and snakes ...and so on...

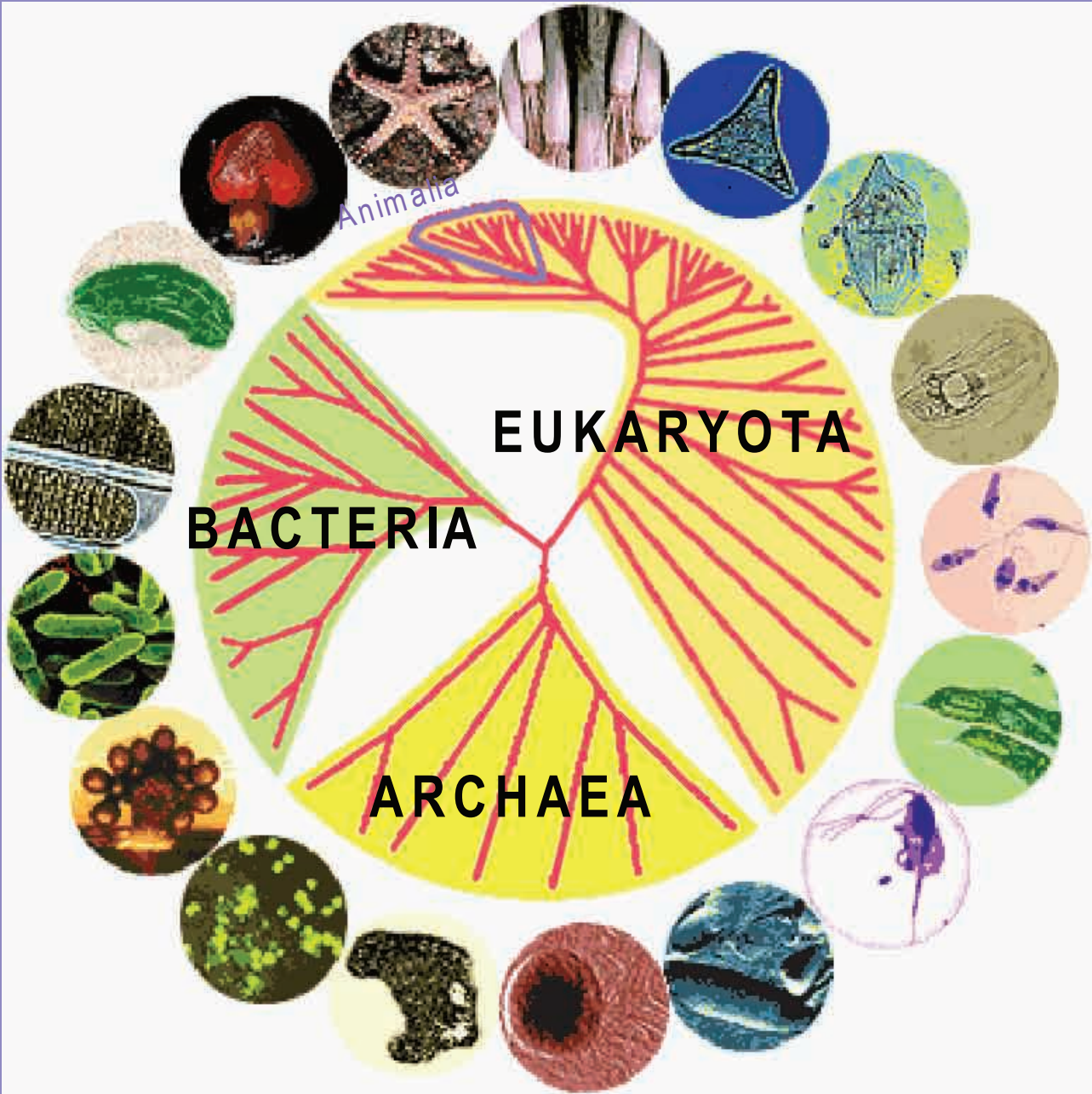
We can build phylogenetic trees that show how different species are interrelated.

VERTEBRATE PHYLOGENY

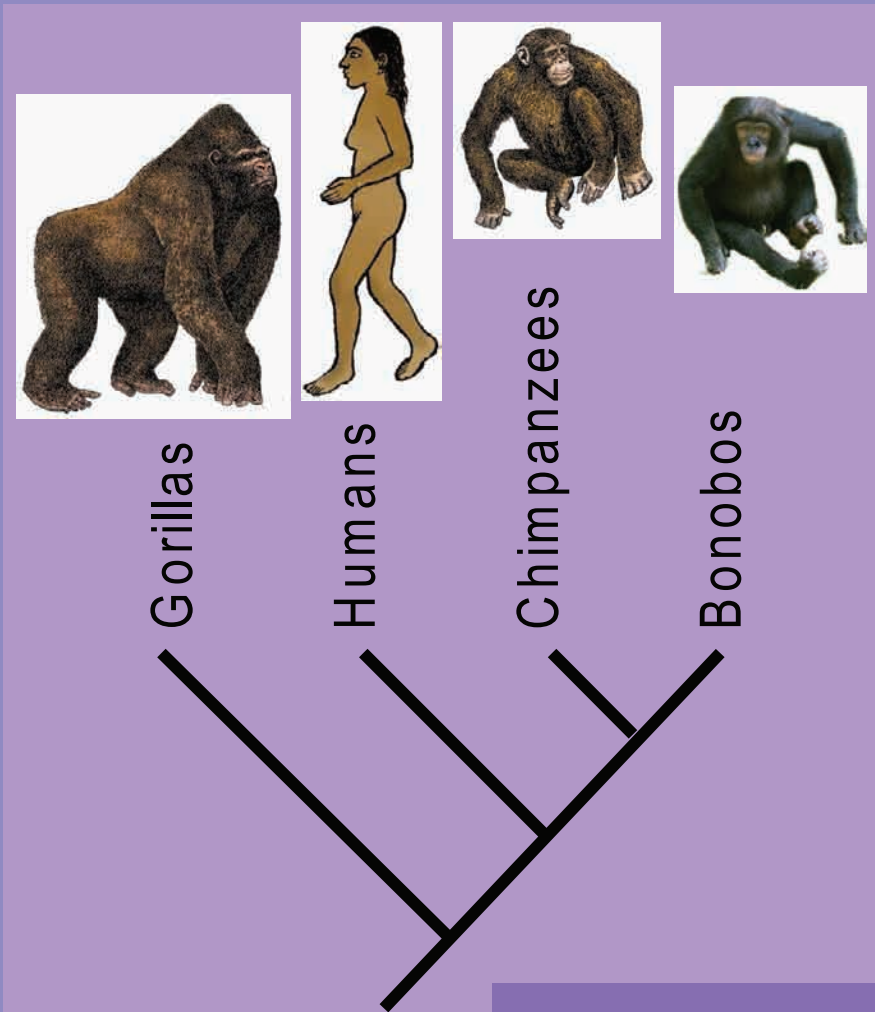




16 Classification shows us how all species are interrelated



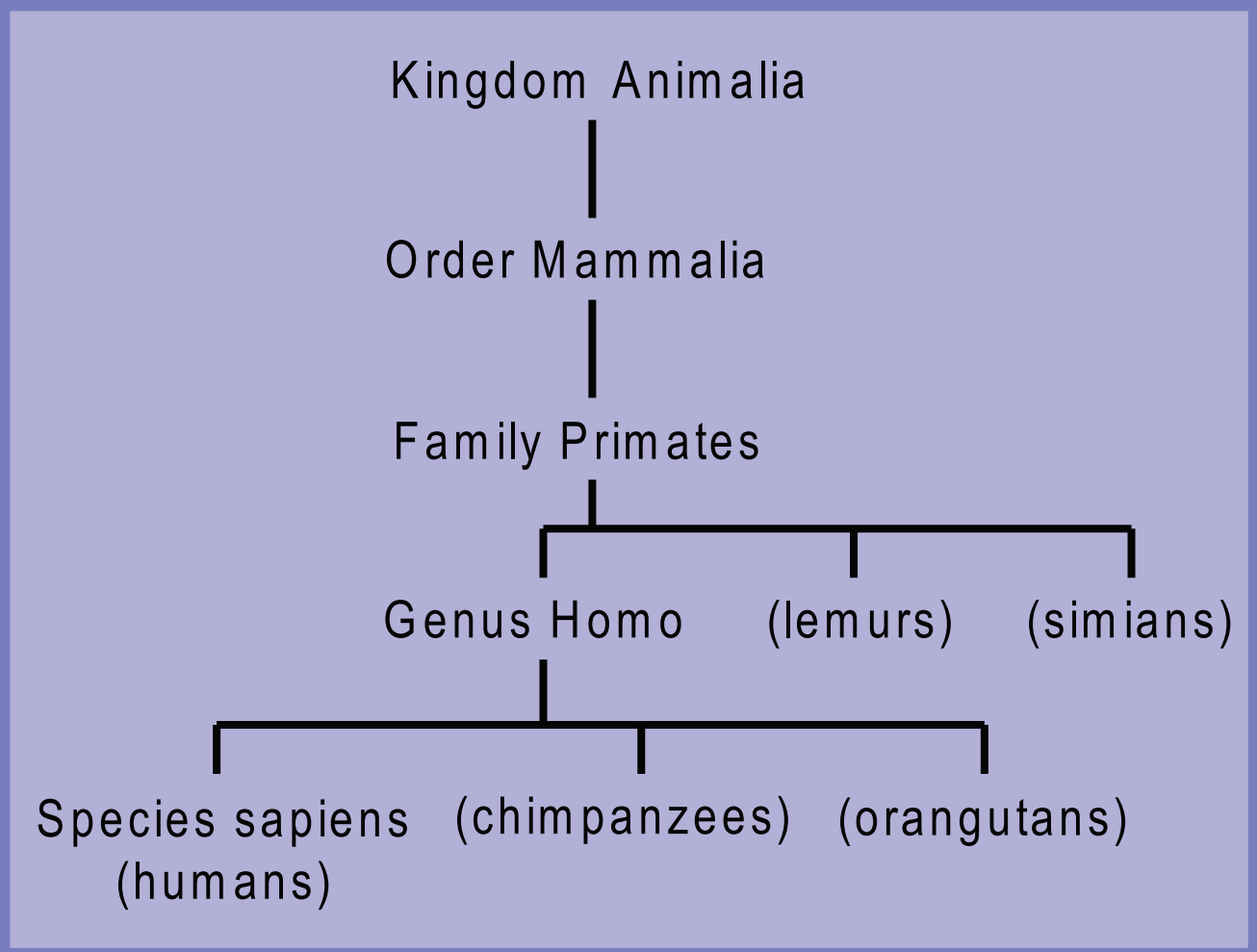
...even humans!



But aren't people special?

Humans, chimpanzees, monkeys, and apes are all PRIMATES

The classification by Linnaeus (1735):



Who are we?

A modern classification of humans:

Domain	Eukarya
Kingdom	Animalia
Phylum	Chordata
Subphylum	Vertebrata
Class	Mammalia
Subclass	Eutheria
Order	Primates
Suborder	Anthropoidea
Superfamily	Hominoidea
Family	Hominidae
Subfamily	Homininae
Tribe	Hominini
Genus	Homo
Species	sapiens
Subspecies	sapiens

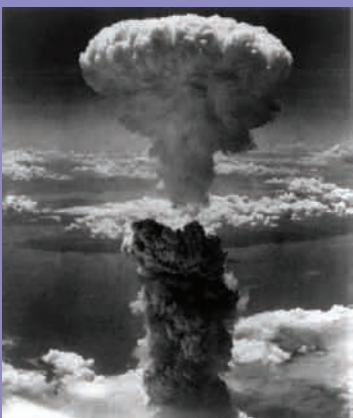
Research to classify humans continues. Each new human fossil adds more evidence concerning evolutionary relationships.

However, Linnaeus believed that humans were special beings in God's creation.

...not savage animals?

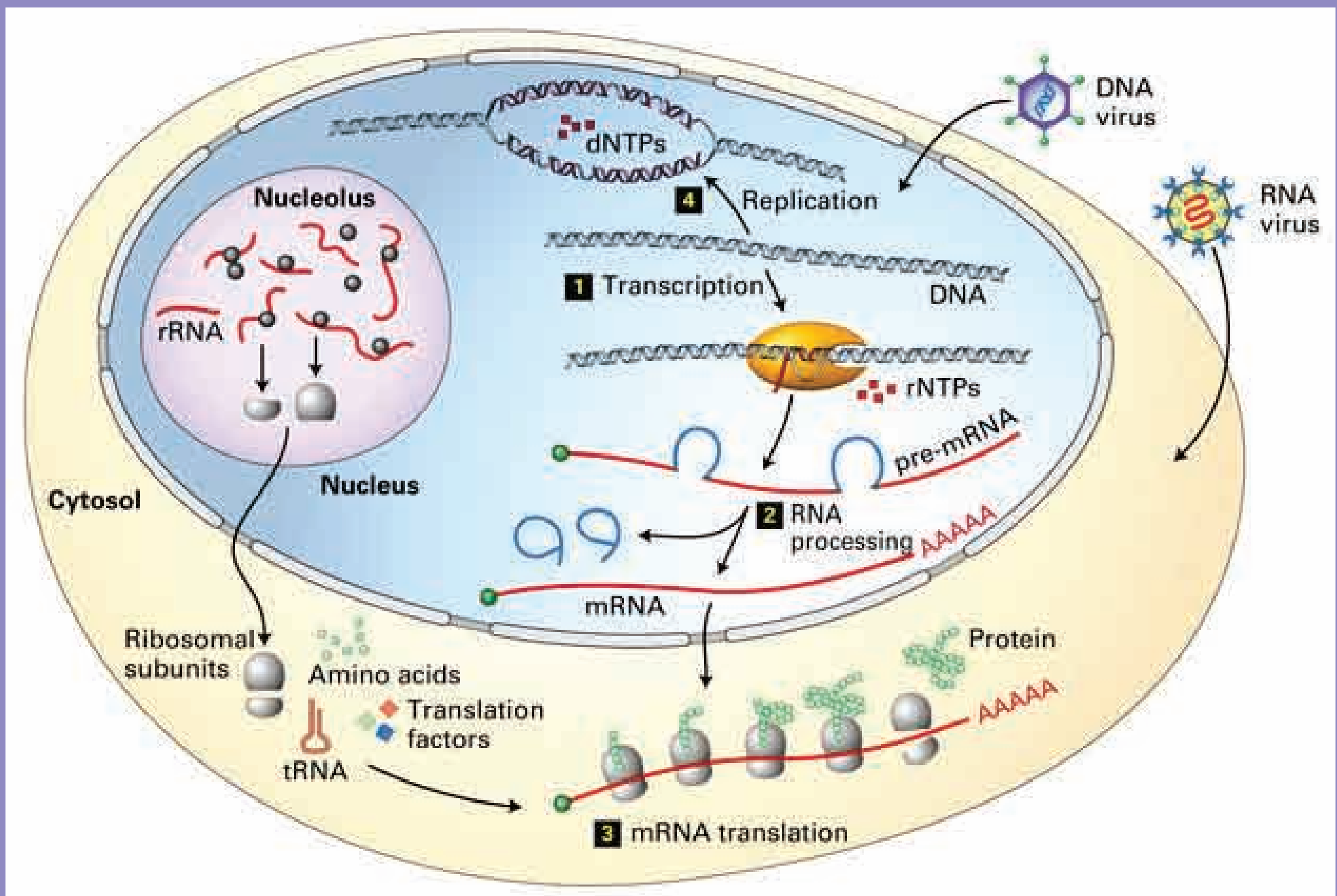


Who are the savage animals?



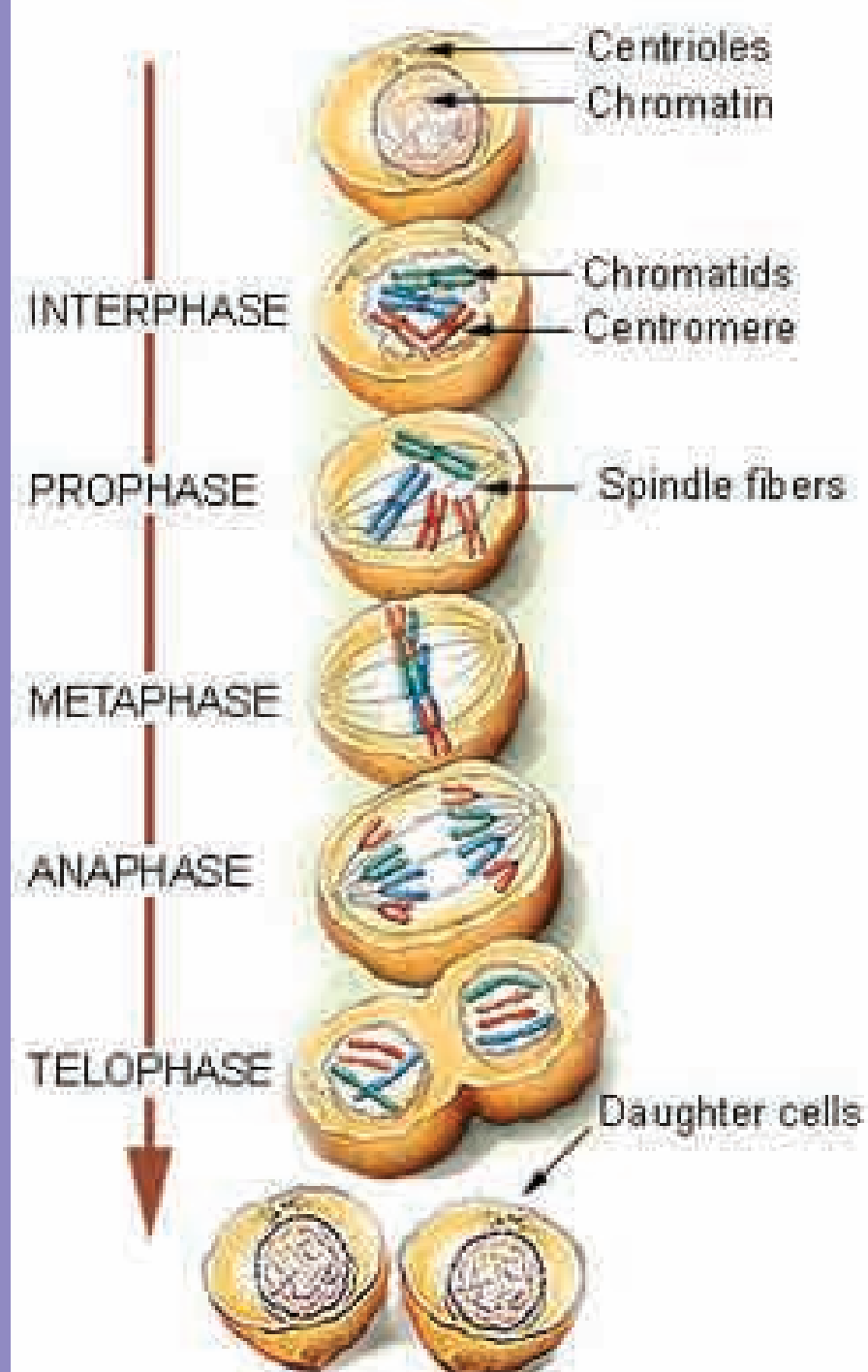


# 17 All life on earth is based on the same molecular biology

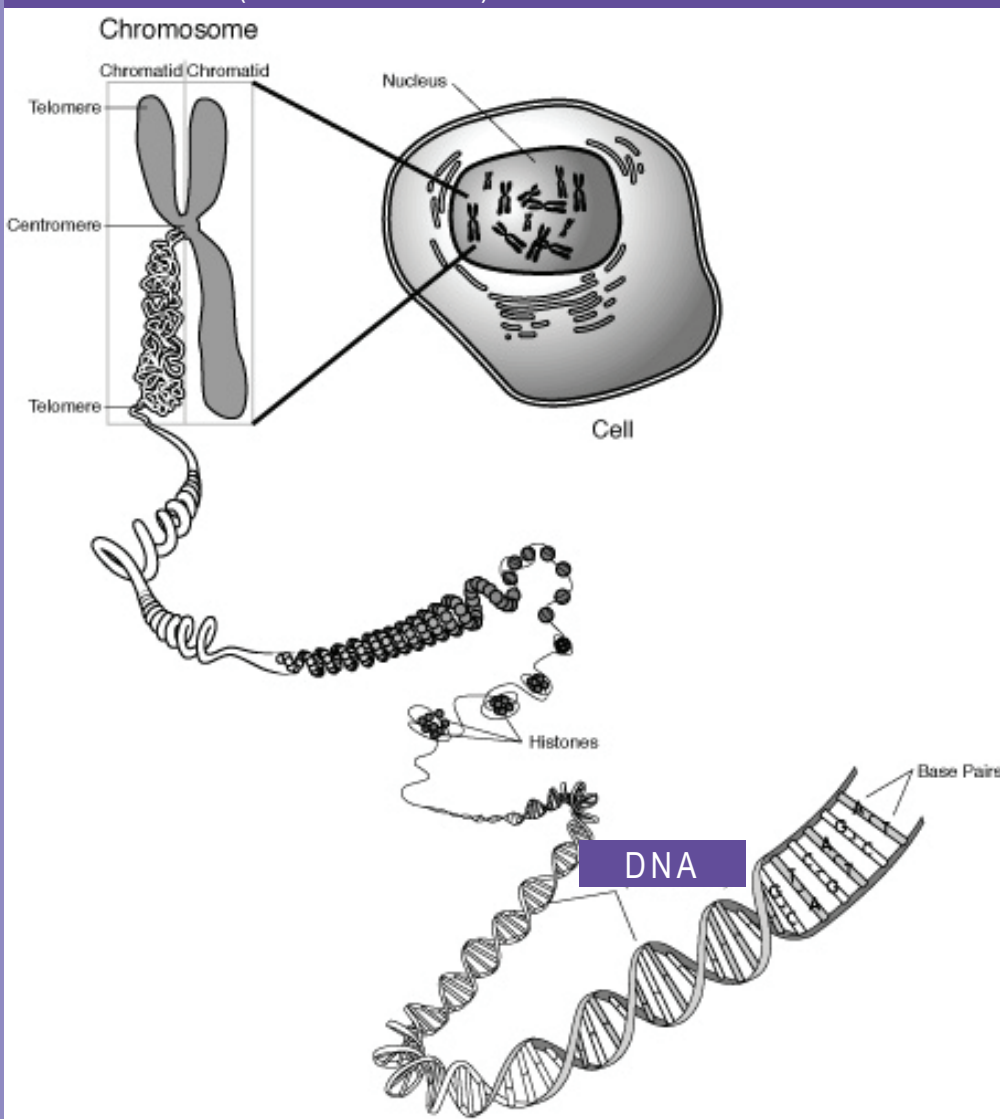


All forms of life consist of cells that reproduce. When a cell reproduces, it divides into two cells, each containing a copy of the genetic material.

## Mitosis

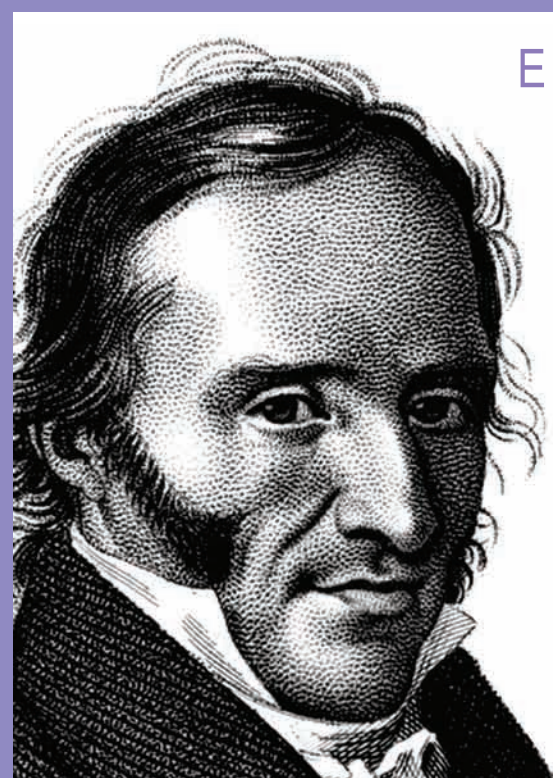
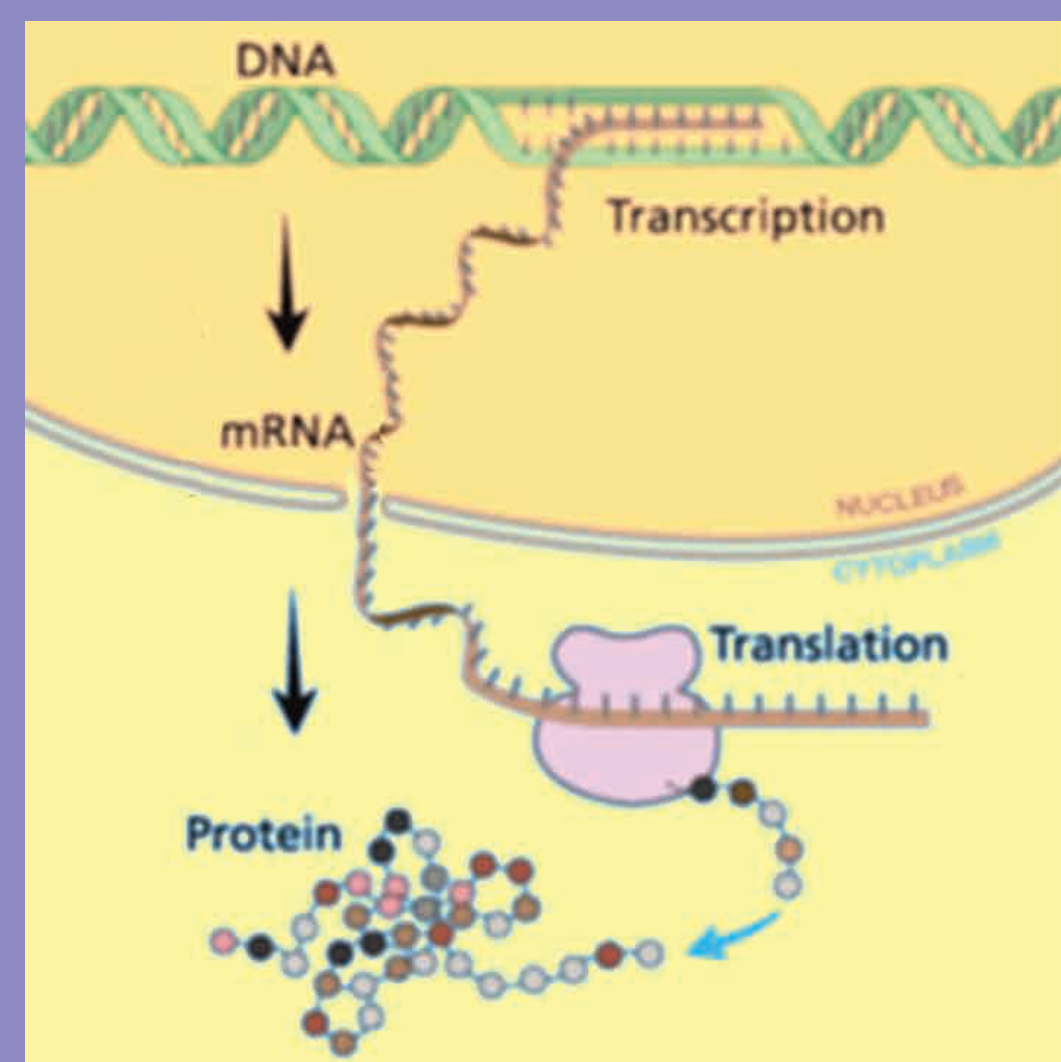


The genetic material (genes) of all forms of life are made of nucleic acids (DNA and RNA).



The basic structures and functions of DNA, RNA, and proteins are similar (and yet different) in all the various forms of life.

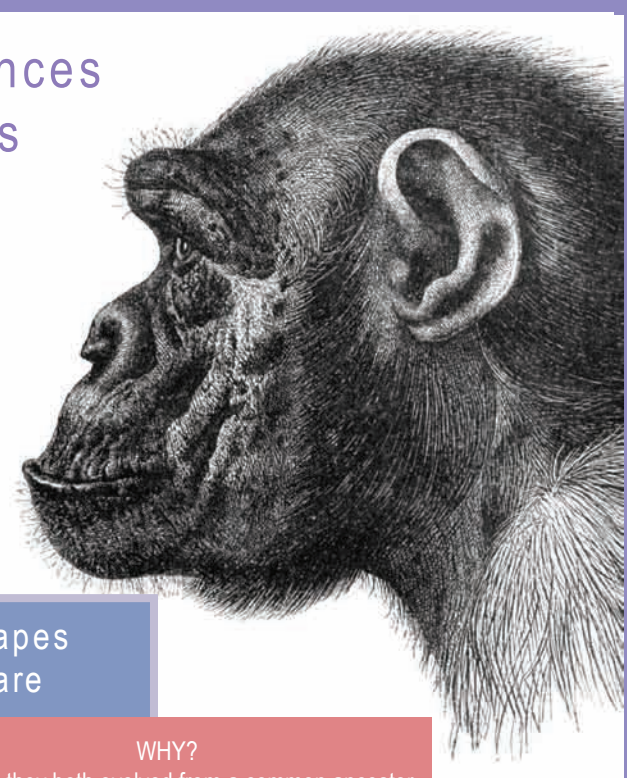
DNA gets transcribed into RNA, which gets translated into proteins, which are used for many functions.



Even the DNA sequences of different species are closely related.

The genes of humans and apes have DNA sequences that are 95 to 98% identical.

WHY?  
because they both evolved from a common ancestor







## No! It is not all in the genes...

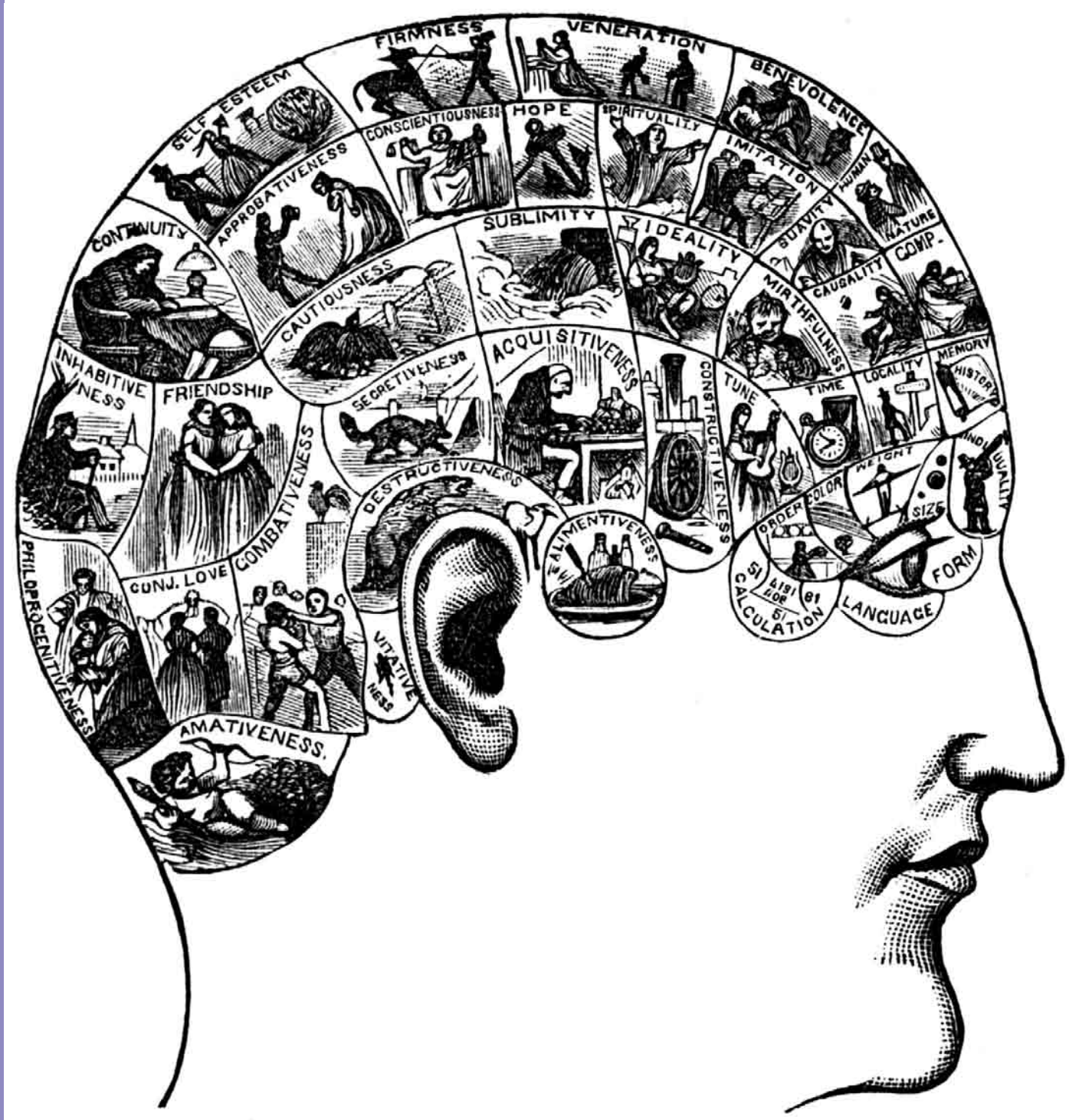
For example, these leaflets look different, but they have the same genes. They were from the same compound leaf and the same individual tree. Every cell in every leaf has practically the same genetic makeup.

No.

Traits are due to complex interactions between genes and their environment.

Not all variations can be passed on to offspring.

## BIOLOGICAL DETERMINISM?



## OR INTERDEPENDENCE?

# BIOLOGICAL DETERMINISM:

the belief that genes determine (almost) everything



Genes for many traits have been found. However, things are not that simple.

## How tall will your children be?

## Are there genes for:

the size of your nose?  
leaf shape?  
eye colour?  
diseases?  
criminal behaviour?  
mother tongue?  
preference for tea or coffee?  
vegetarianism?  
ability to swim?  
intelligence?  
?



## Evidence that evolution occurs:

1. All populations of organisms exhibit variety
2. Classification of organisms reveals similarities
  - All forms of life are related to each other - sharing characteristics
  - We can construct phylogenetic trees to show interrelations
3. Offspring resemble parents
4. Fossil evidence: appearance and extinction of species
5. Biogeography: island species evolved from mainland species
6. All organisms have the same basic molecular biology
  - All organisms contain nucleic acids, which determine proteins, etc.
7. Comparative anatomy
  - Homologous structures: various organisms have structures that have different functions, even though their form is similar - because they evolved from common ancestors.
  - Vestigial structures are found, which are similar to ancestral structures, but with loss of function

## EVOLUTION:

inherited change in a population of organisms

The achievement of Darwin was not only in recognising that evolution has occurred, but in discovering **how** it occurs through **NATURAL SELECTION**.

In order to understand natural selection, Darwin first studied **ARTIFICIAL SELECTION**.

Let's also look first at artificial selection in order to understand natural selection.

Darwin studied artificial selection in horses, dogs, cattle, and pigeons...



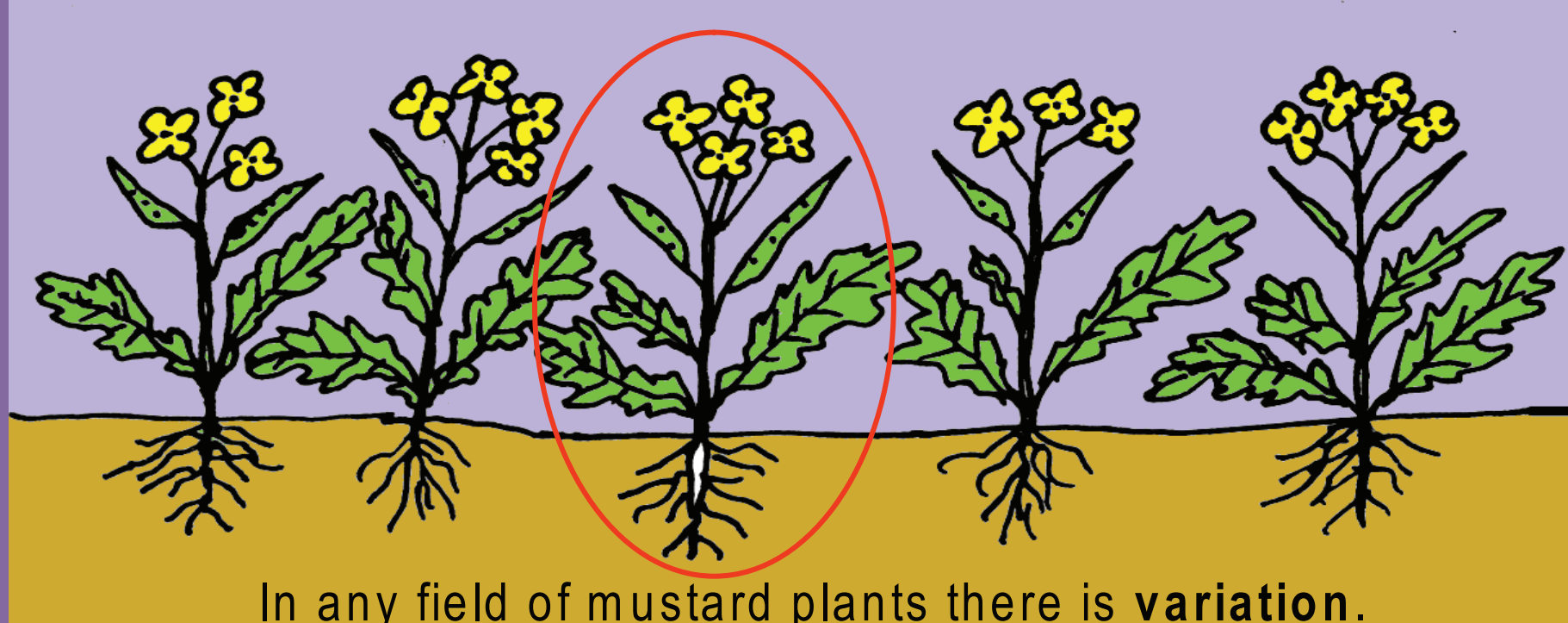


# ARTIFICIAL SELECTION:

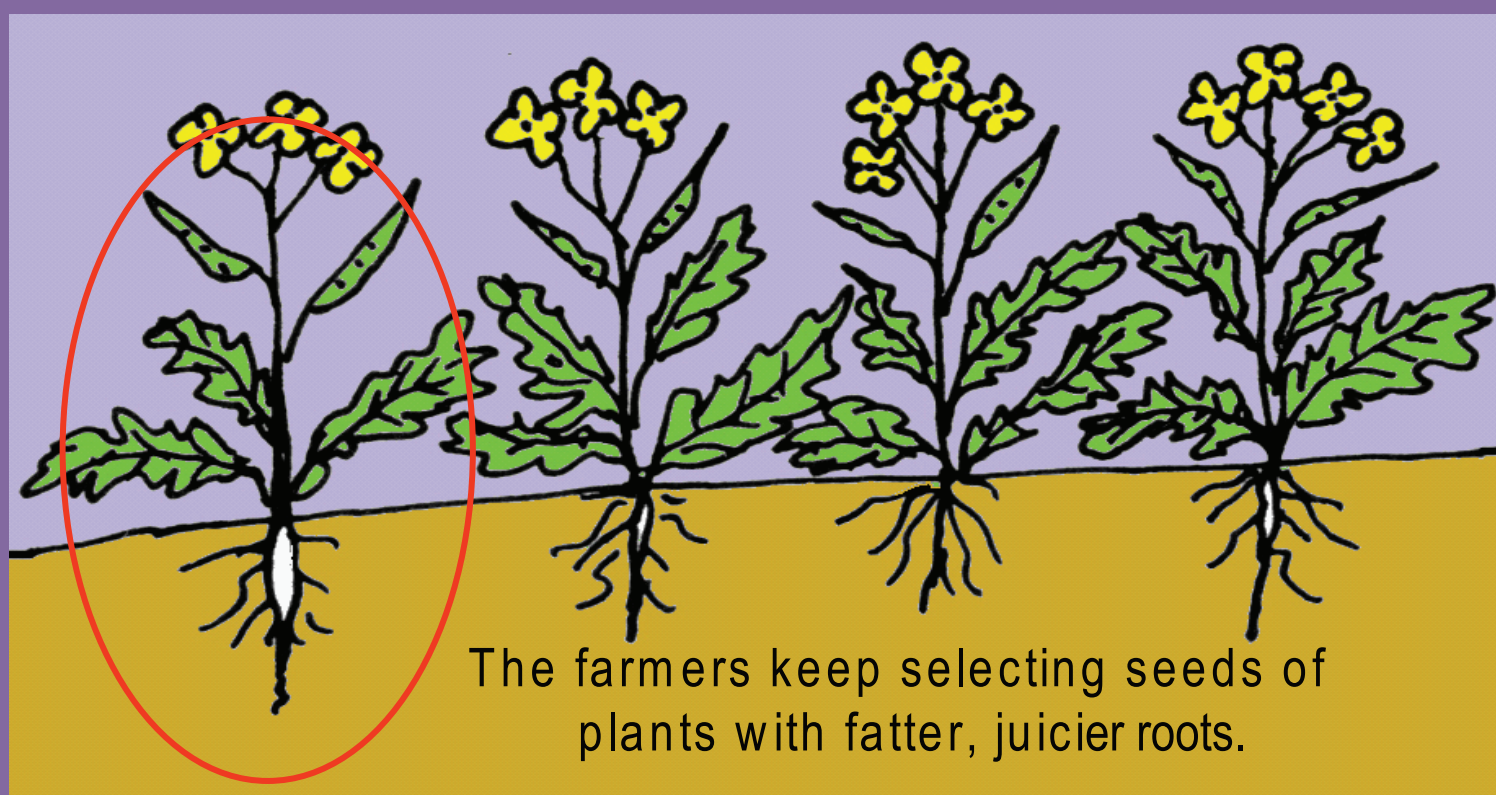
People select varieties they want

For example, let's go back to many thousands of years ago. when the first farmers begin to grow wild mustard...

Suppose the early farmers like to eat mustard roots that are fat and juicy.



When they select the seeds for the next year's crop, they will choose those from the plants with the fat, tasty roots.



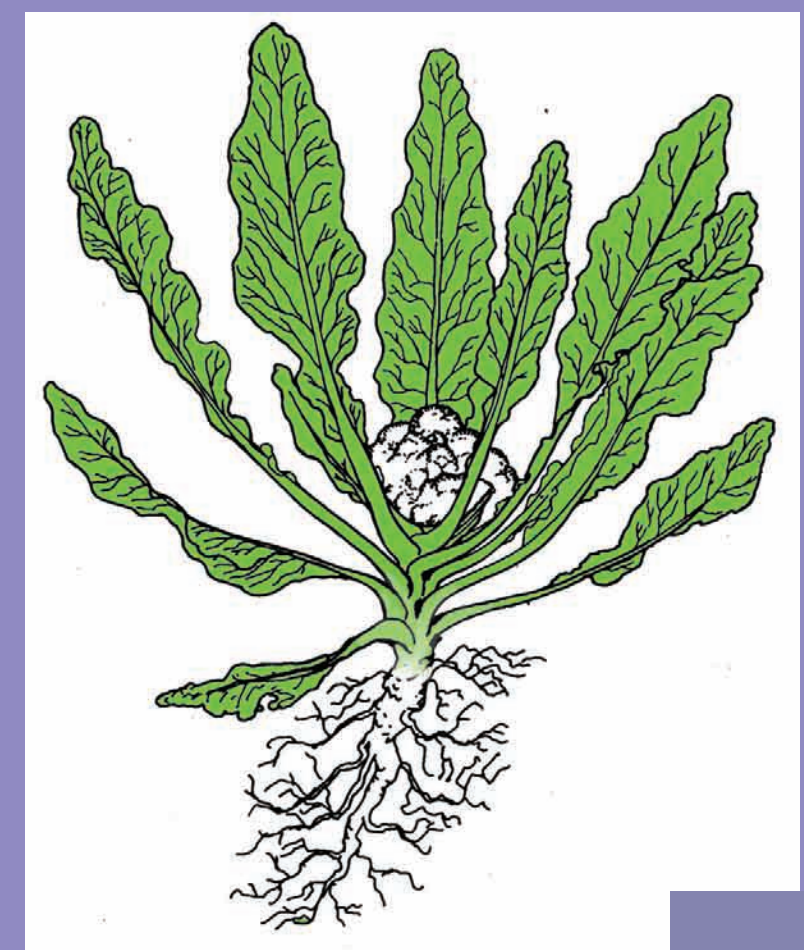
After a number of generations of selecting seeds of the desirable plants, the crops tend to have more plants with fatter, juicier roots.



After many, many generations, look what has happened:  
Mooli (white radish) has evolved!

Similarly, by selecting mustard plants with some other desirable characteristic, farmers in other places got the following crops from wild mustard:

- Mustard greens (saag)
- Mustard seeds (rai, sarson)
- Mustard oil
- Cabbage (bandgobi)
- Broccoli
- Kohlrabi
- Turnips (shalgam)
- Rutabaga
- Moongra
- Red radishes



It is not easy to find out where crops came from and how they evolved. Research is being conducted to answer these questions...

By **ARTIFICIAL SELECTION** people have developed many new varieties of food plants.

Could a similar thing happen without people?  
Could nature do this?



# NATURAL SELECTION

is like artificial selection but without any act of design:

## WHAT IS NATURAL SELECTION?

Let's look at a recent example...

### PEPPERED MOTHS

before Industrial Development:



A population with heritable variation

Peppered moths after industrial development:



What happened to the moth population?  
It evolved due to natural selection.



# The moth population changed due to NATURAL SELECTION

The change did not occur by design.

Some of the moths in the original population just happened to already have a mutation that caused different colouration.

The mutation did not occur because of a change in environment.

The moths did not change colour in order to adapt to the environment

The population of moths did not change because the birds wanted it to.



Answer these questions:

- (1) Is there ever any population in which there is no variation?
- (2) Did the birds cause the peppered moths to change colour?
- (3) Did the moths want to change their colour so that they would be hidden?
- (4) Did the birds want the moths to change colour?
- (5) Did individual moths change their colour or did the population of moths change colour?
- (6) What are the differences and similarities between artificial and natural selection?



# EVOLUTION IS NOT A STRUGGLE FOR EXISTENCE

There is no purpose in evolution.

Although Darwin used the phrase “Struggle for Existence”, he realised that evolution is not due to competition between individuals. Rather, individuals (as well as populations) are interdependent on each other and on their environment. Evolution occurs without any effort or purpose to evolve.

“I should premise that I use the term Struggle for Existence in a large and metaphorical sense, including dependence of one being on another, and including (which is more important) not only the life of the individual, but success in leaving progeny. Two canine animals in a time of dearth, may be truly said to struggle with each other which shall get food and live. But a plant on the edge of a desert is said to struggle for life against the drought, though more properly it should be said to be dependent on the moisture.”

[Charles Darwin, On the Origin of Species, 1st edition, 1859]



Some people mistakenly think evolution occurs due to a struggle for existence in which only the fittest individuals survive. They apply this to human society to conclude that an individual, or groups of individuals should fight to be the most powerful. They rationalise that it is inevitable that the weak die out. Thus they can justify social injustices.

LIFE INVOLVES BOTH STRUGGLE AND COOPERATION.



# Why is it so difficult to understand evolution by natural selection?

Partly because we often think in a teleological way.

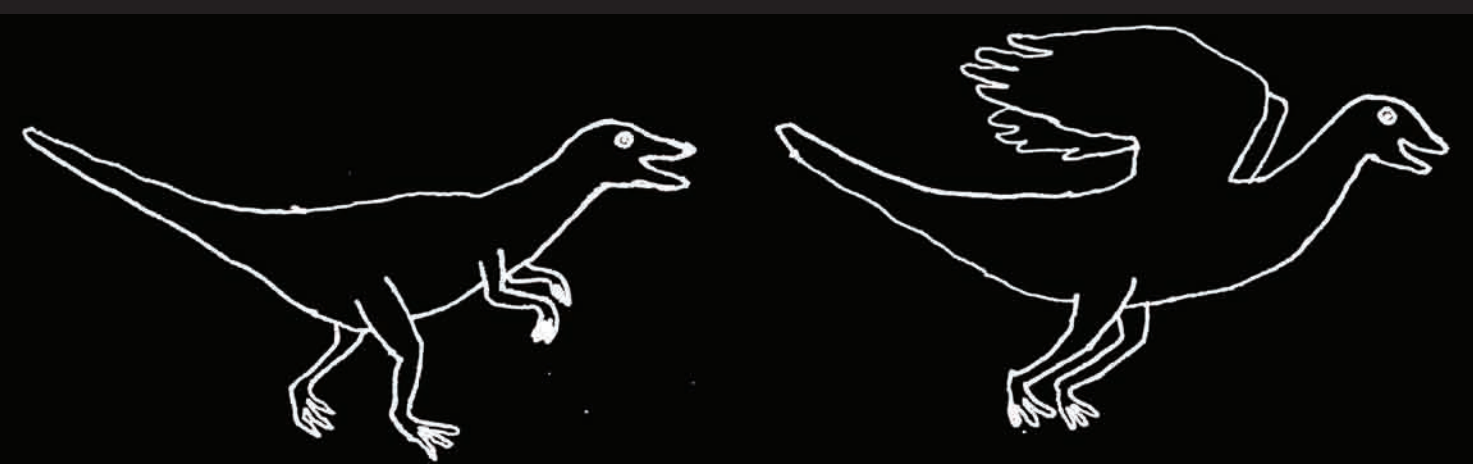
Teleology is the belief that things happen for some purpose.

Happening for a purpose is different from happening for a reason. For example, the peppered moth population changed for a reason: birds were more likely to eat one colour. But the population did not change for the purpose of hiding from birds.

## TELEOLOGY



Mice exist for cats to eat.

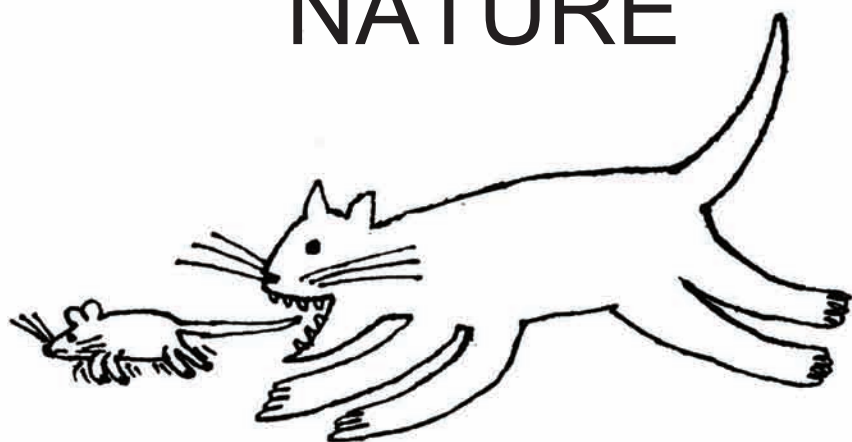


I need to fly, so I grow wings.

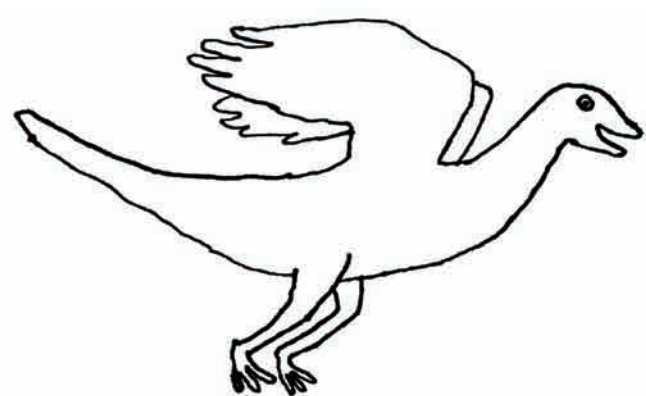
According to teleology,  
FUNCTION  
DETERMINES  
FORM

For example, according to a teleological way of thinking, the purpose of mice is to provide food for cats, and the purpose of wings is to fly. The existence of a particular form (like wings) is the result of the need for a particular function (flying).

## NATURE



Mice exist, then cats eat them.



I grew wings, so I use them to fly.

But in natural selection,  
FORM  
DETERMINES  
FUNCTION:

Mice do not exist because cats need food. A particular form (like wings) exists, and then the form is used for some function (flying).

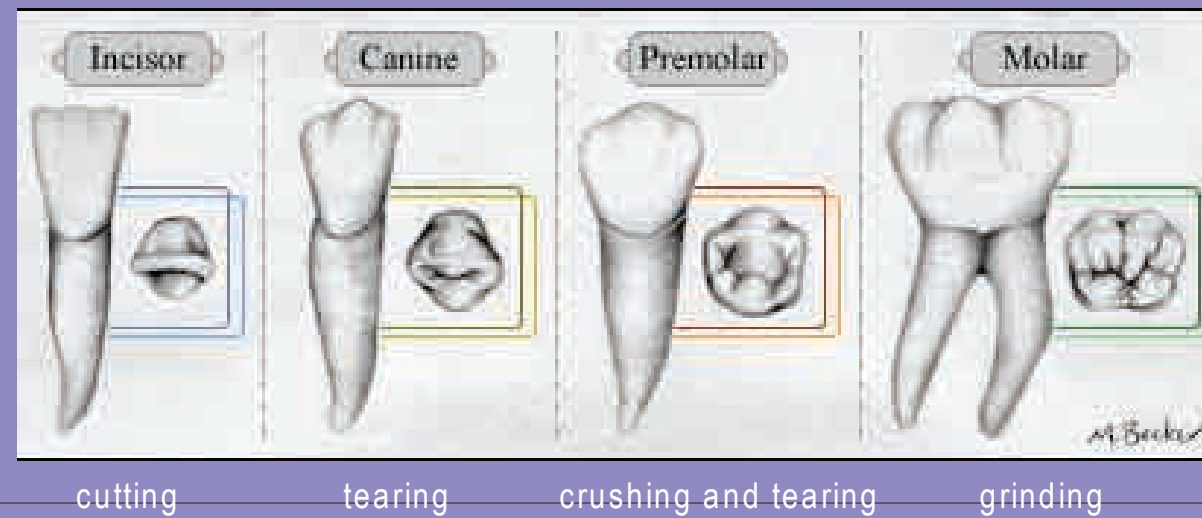
This is non-teleological. There is no pre-determined purpose for the existence of anything.

EVOLUTION BY NATURAL SELECTION IS NON-TELEOLOGICAL



# Is the form of an organism determined by its function?

Aristotle was an ancient Greek philosopher who asked this question. For example, he asked, “Do we have different kinds of teeth because they were each designed for a different purpose?”



Aristotle was a true philosopher. This means, he questioned his own beliefs. He wondered:

“So what hinders the different parts (of the body) from having this merely accidental relation in nature? as the teeth, for example, grow by necessity, the front ones sharp, adapted for dividing, and the grinders flat, and serviceable for masticating the food; since they were not made for the sake of this, but it was the result of accident. And in like manner as to other parts in which there appears to exist an adaptation to an end. Wheresoever, therefore, all things together (that is all the parts of one whole) happened like as if they were made for the sake of something, these were preserved, having been appropriately constituted by an internal spontaneity; and whatsoever things were not thus constituted, perished and still perish.”

In other words, Aristotle is wondering whether instead of being made for different purposes, the different kinds of teeth just happened by chance to have different shapes, and then different uses for these shapes were found. This characteristic is preserved, while the characteristic of having teeth with shapes that are not useful is not preserved.

But Aristotle rejected this argument. He continued:

“Such are the arguments (and others of the kind) which may cause difficulty on this point. Yet it is impossible that this should be the true view. For teeth and all other natural things either invariably or normally come about in a given way; but of not one of the results of chance or spontaneity is this true. We do not ascribe to chance or mere coincidence the frequency of rain in winter, but frequent rain in summer we do; nor heat in the dog-days, but only if we have it in winter. If then, it is agreed that things are either the result of coincidence or for an end, and these cannot be the result of coincidence or spontaneity, it follows that they must be for an end; and that such things are all due to nature even the champions of the theory which is before us would agree. Therefore action for an end is present in things which come to be and are by nature.”

Aristotle reasoned that if a form always fits very well to a particular function, then it must have that form because it was designed to perform that function. Any other explanation would be implausible, if not impossible.

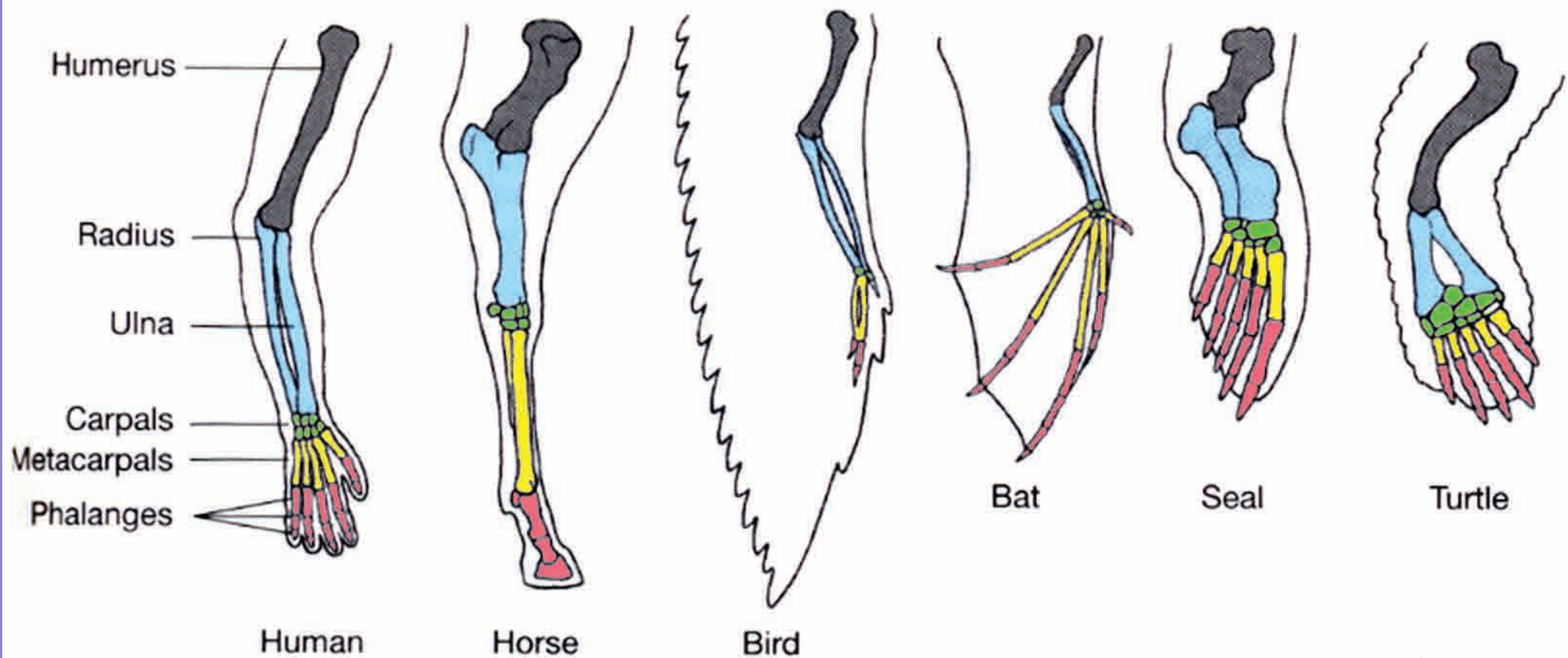
More than 2000 years later, Darwin proved Aristotle to be wrong: Different forms occur by chance, and then functions are found for these forms.



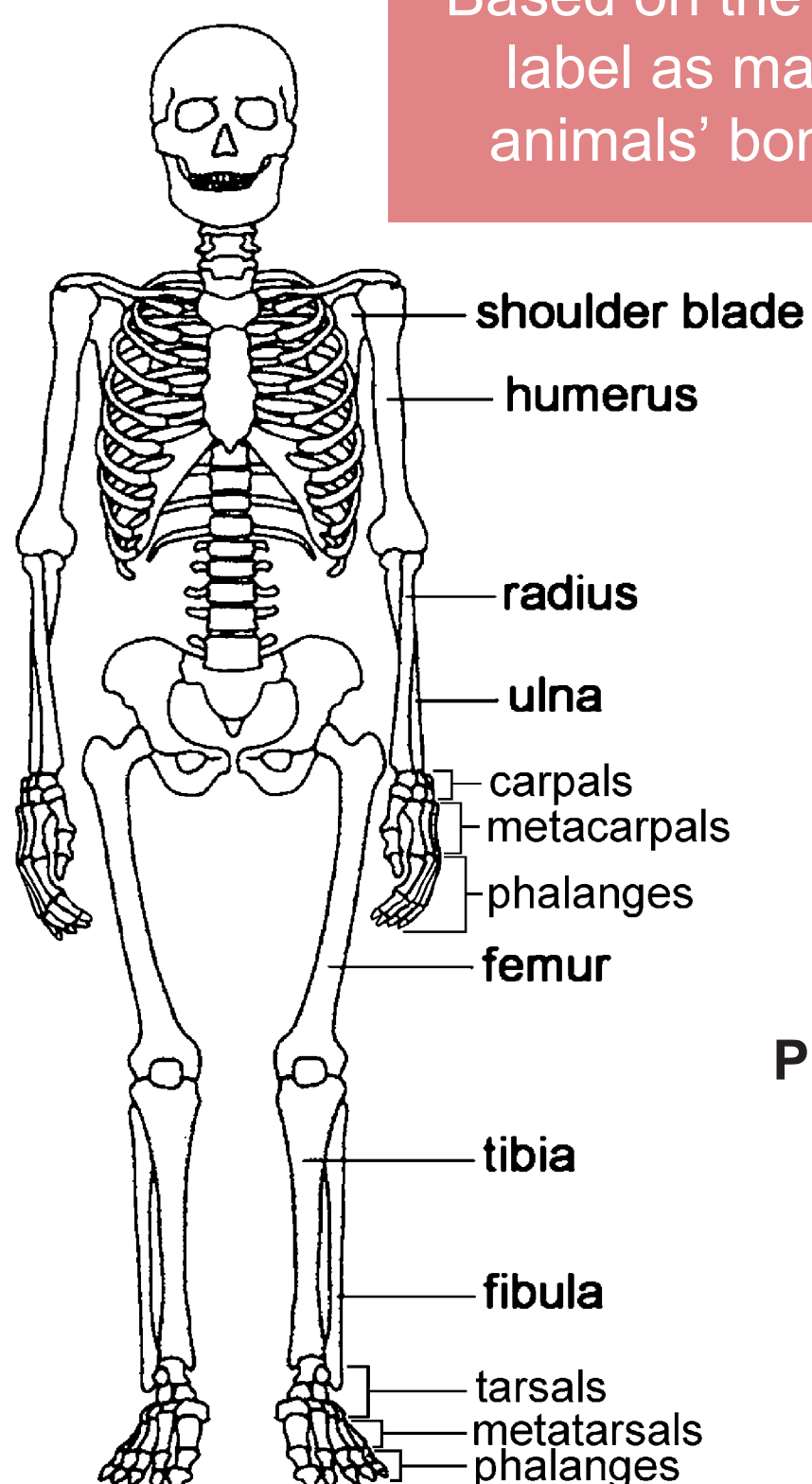
# HOMOLOGOUS STRUCTURES

The same basic structure serves different purposes in different species.

Which bones are homologous?

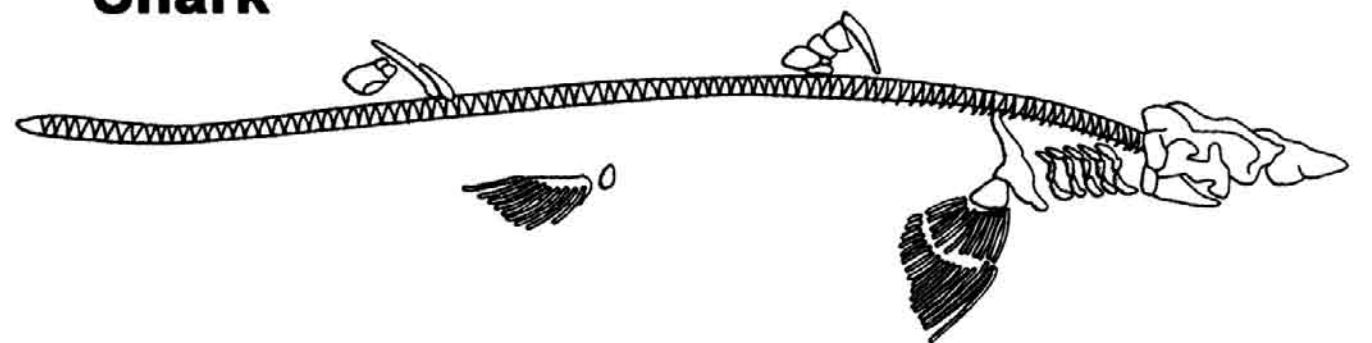


What is the function of each of these limbs?

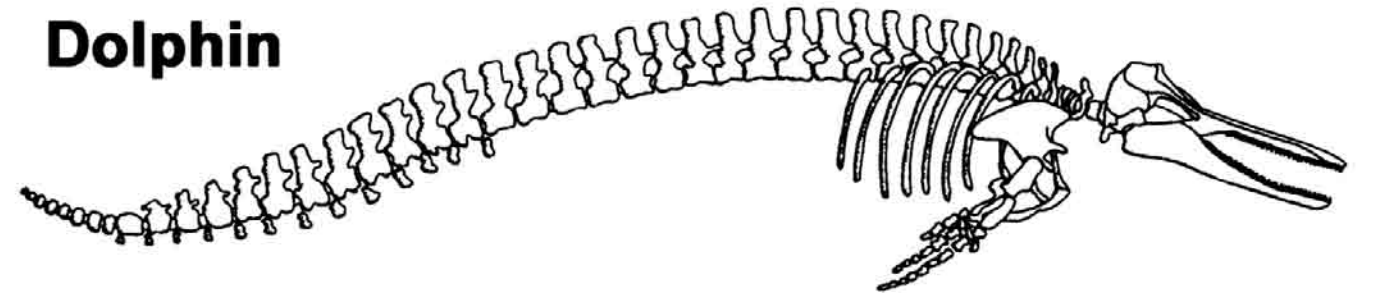


Based on the human skeleton, label as many of the other animals' bones as you can.

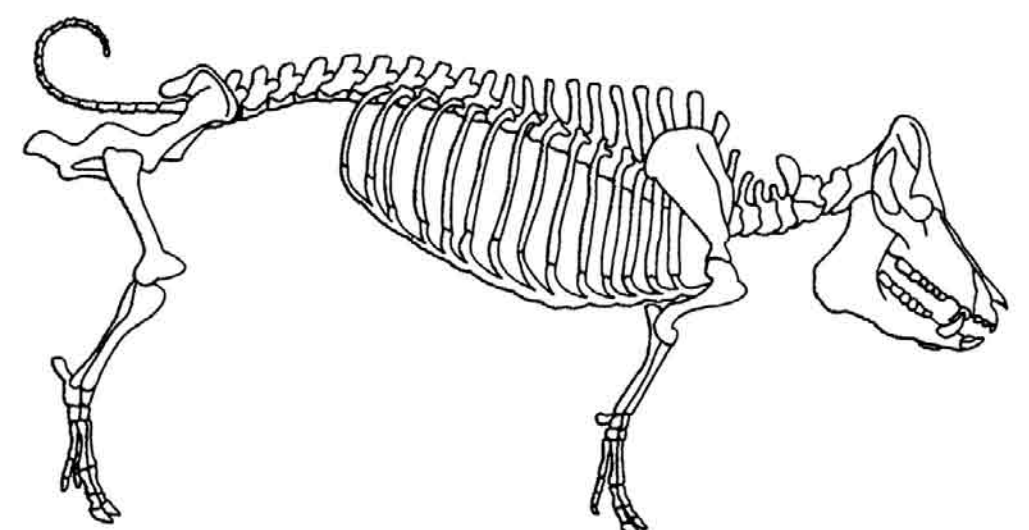
**Shark**



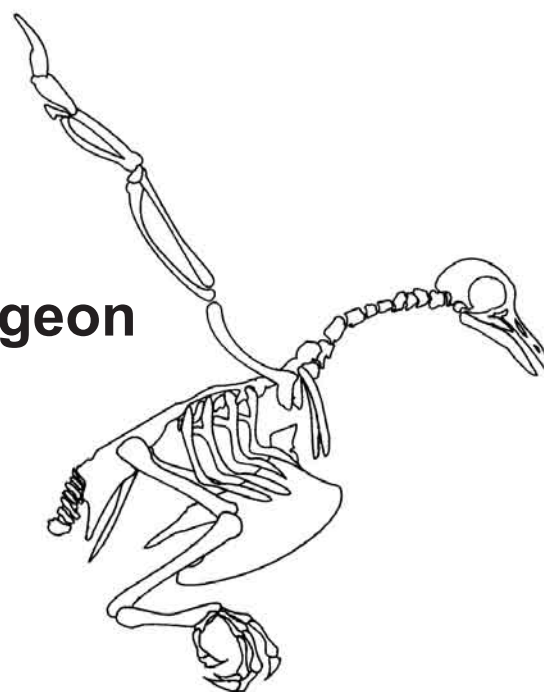
**Dolphin**



**Pig**



**Pigeon**



Why are the structures so similar and the functions so different?  
...because all the species have a common ancestor.

Variations in the structures appeared by chance in the ancestors, and different functions for these variations were found.



# EVOLUTION BY NATURAL SELECTION

(1) Individuals in any population have both similarities and variations in their genomes. Throughout their lives, individuals' genomes interact with their environments to cause similarities and variations in traits.

(2) Depending on their environment, individuals with certain variants of these traits will survive and reproduce more than individuals with other variants. Therefore the population evolves.

## NATURAL SELECTION

is not a purposeful, creative act.

It is a mindless editing mechanism.

There is no goal in evolution.

No form of life is more perfect than any other form of life.

All present-day organisms have been evolving for an equally long period of time, since they all arose from the same ancestor.

Organisms or populations of organisms do not adapt to or fit their environments.

All environments keep changing.

All populations keep changing.

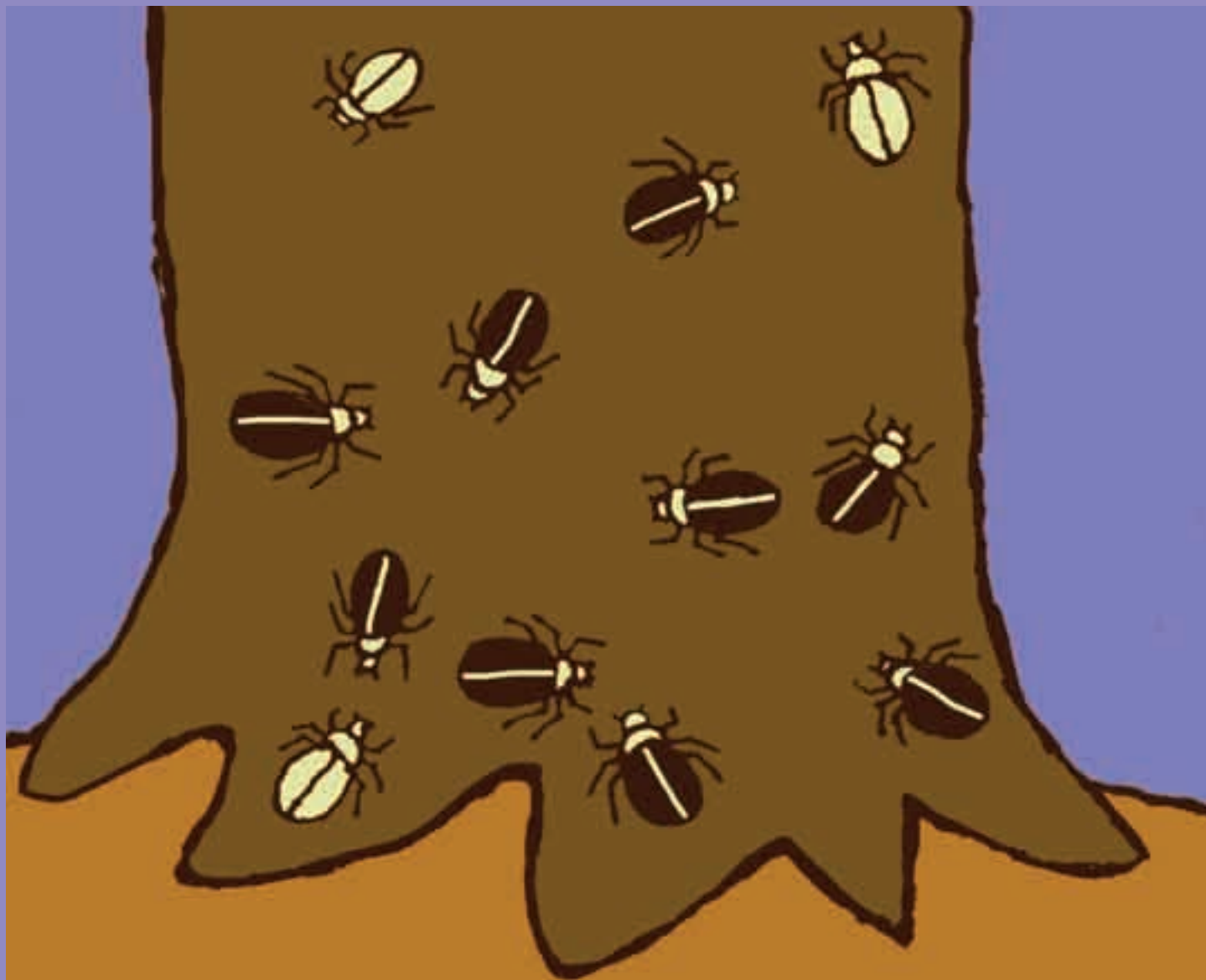
Sometimes populations evolve as if they are adapting to their environments. Actually what happens is that the population happens to have variations, and individuals with certain variations will be less apt to survive and reproduce.



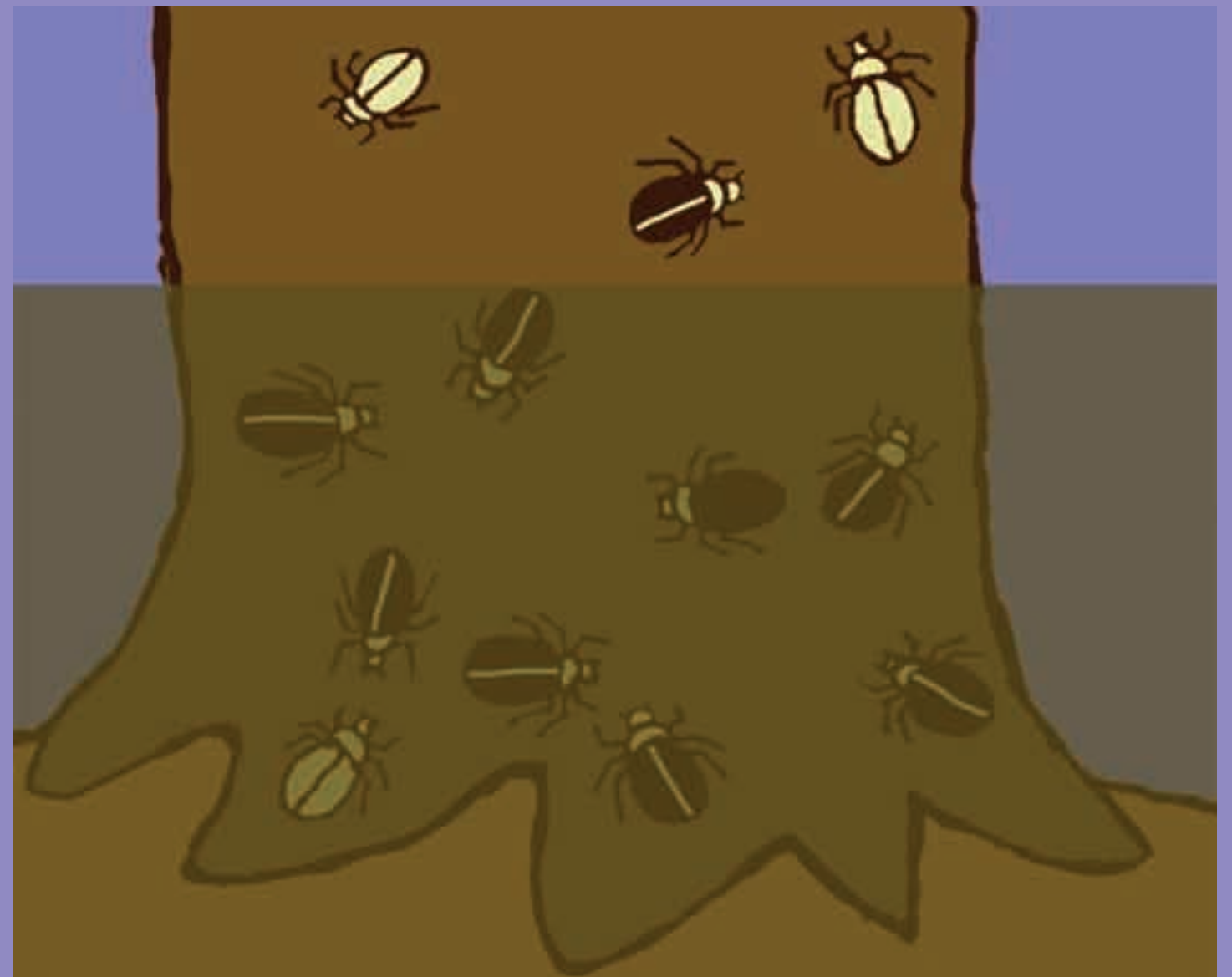


Besides natural selection, there are also some other mechanisms of evolution:

## GENETIC DRIFT



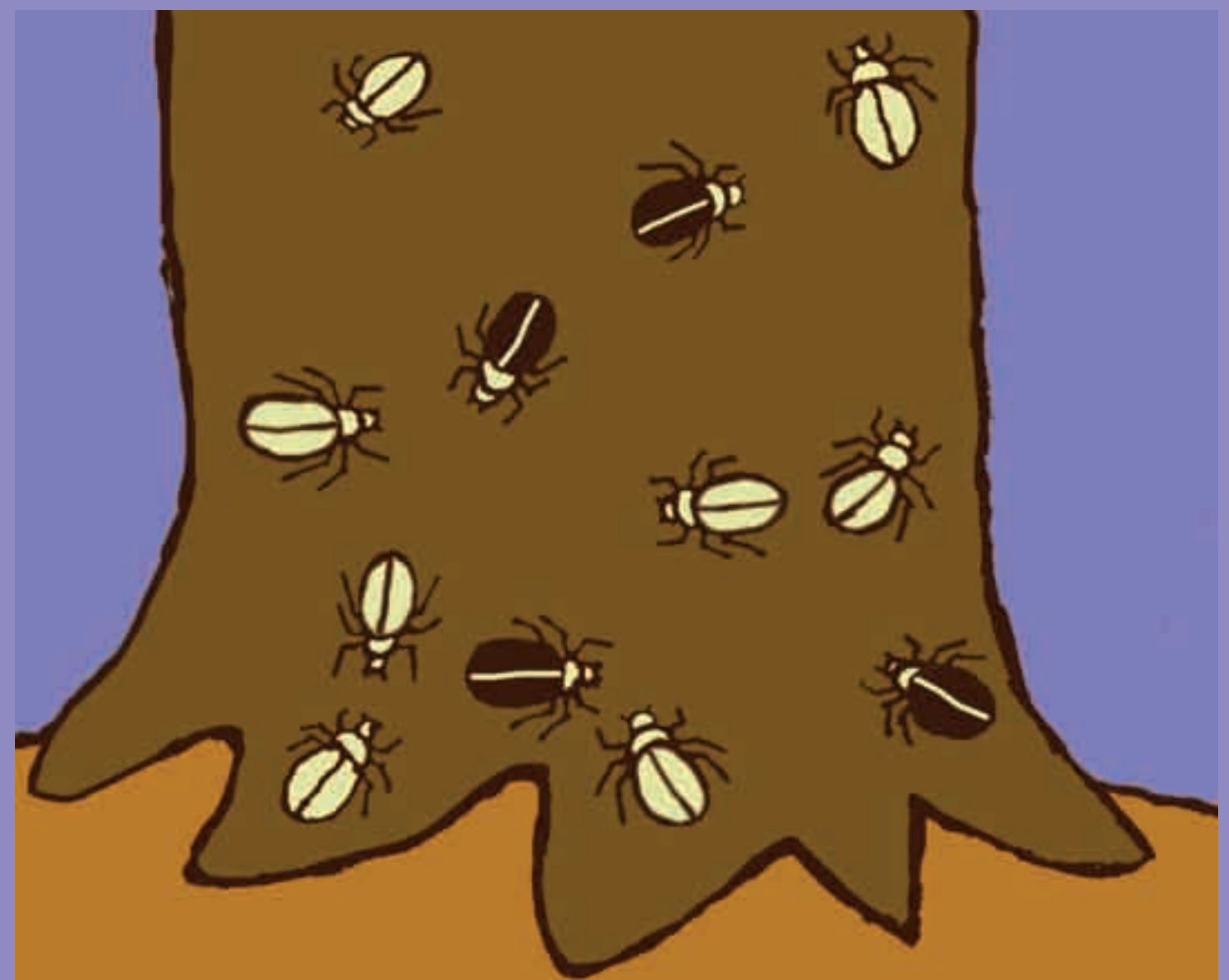
A population of beetles with heritable individual variation.



Suppose a flood wipes out part of the population.



By chance, part of the population survives.



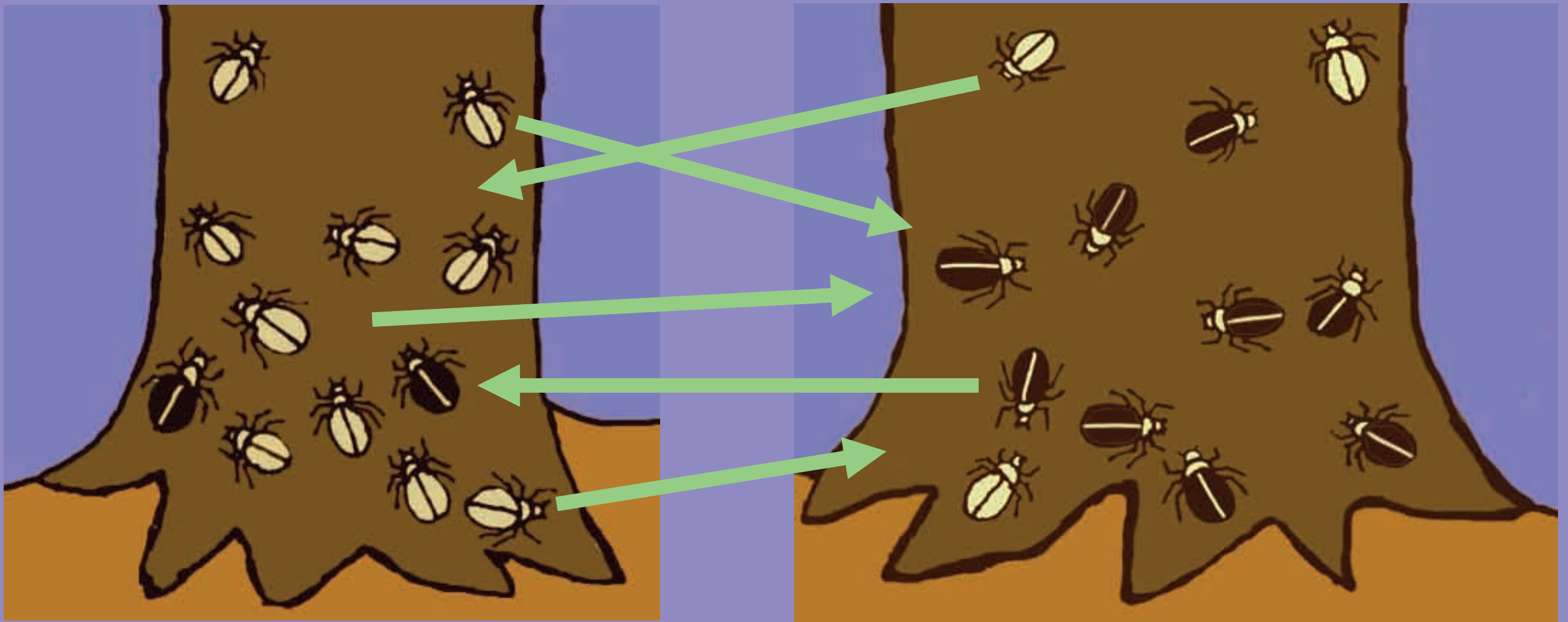
The survivors reproduce. Thus, by chance, the gene pool of the population has changed. The population is now mostly light coloured.

When we say it happened by chance, we do not mean that it happened without reason - but that the reason was not designed to give the particular effect.

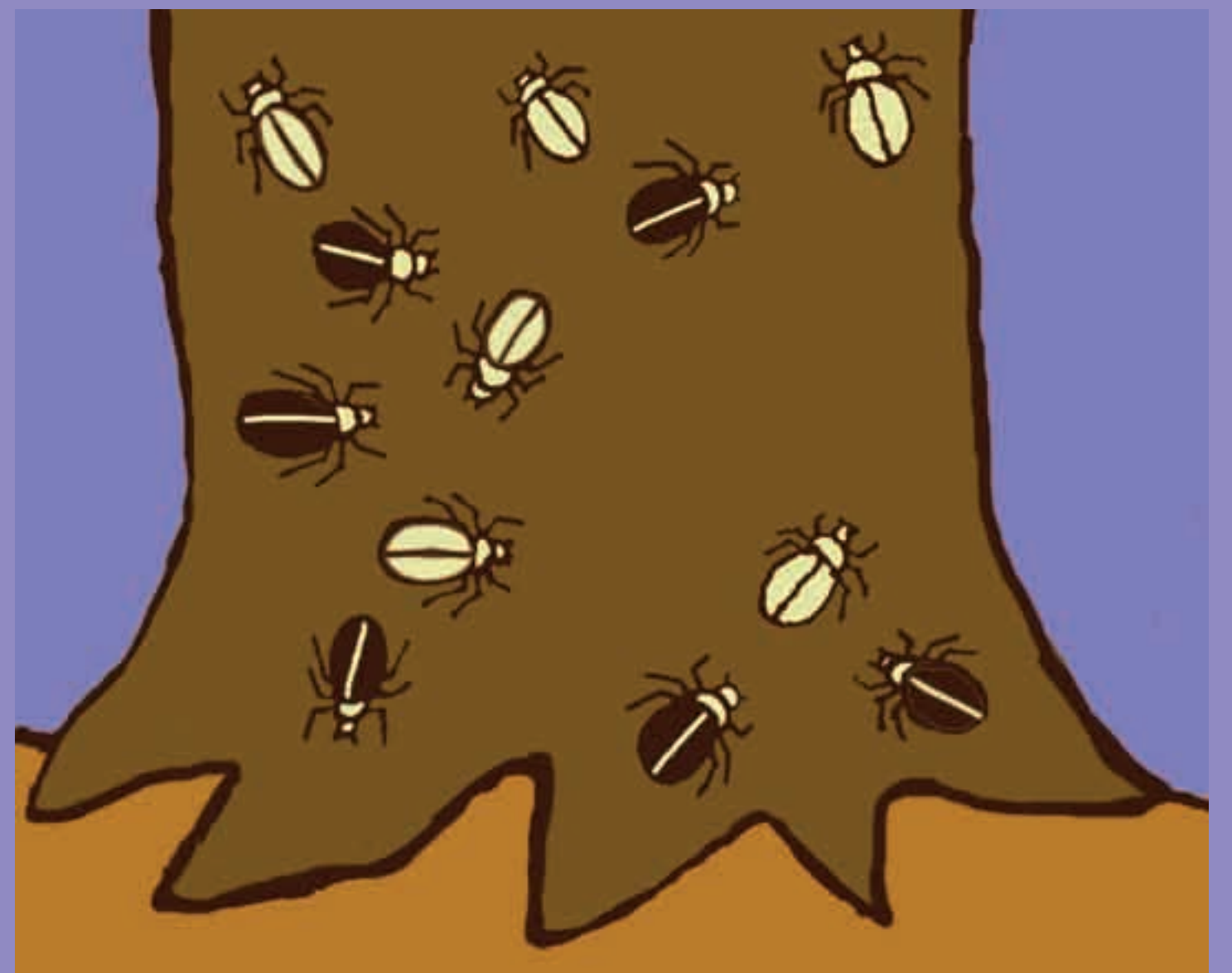
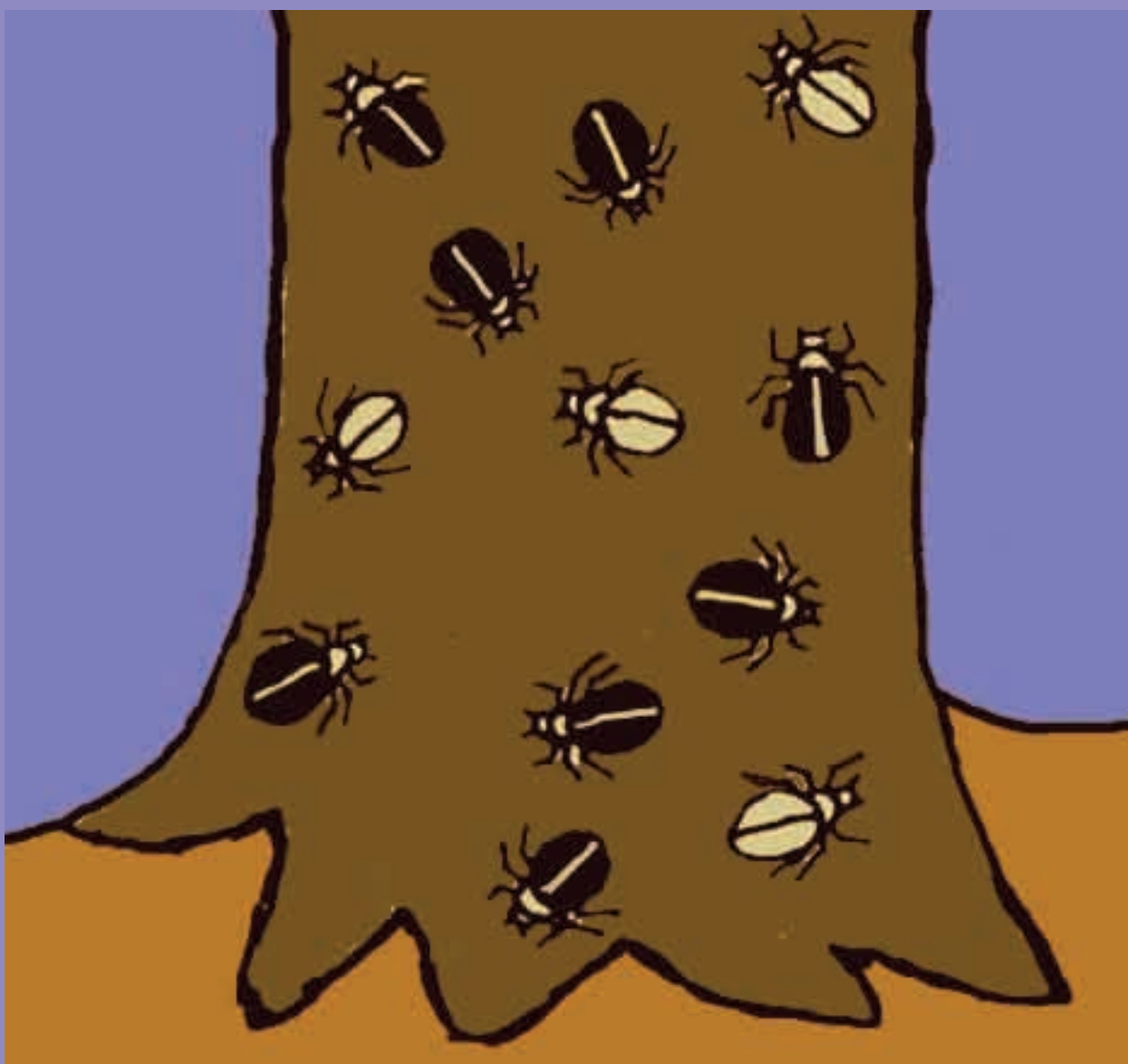
The gene pool is the collection of all the versions of all the genes in all the individuals in a population.



## MIGRATION (GENE FLOW)



Migration of fertile individuals results in the movement of versions of genes (alleles) between two populations.



This changes the gene pool of both populations.

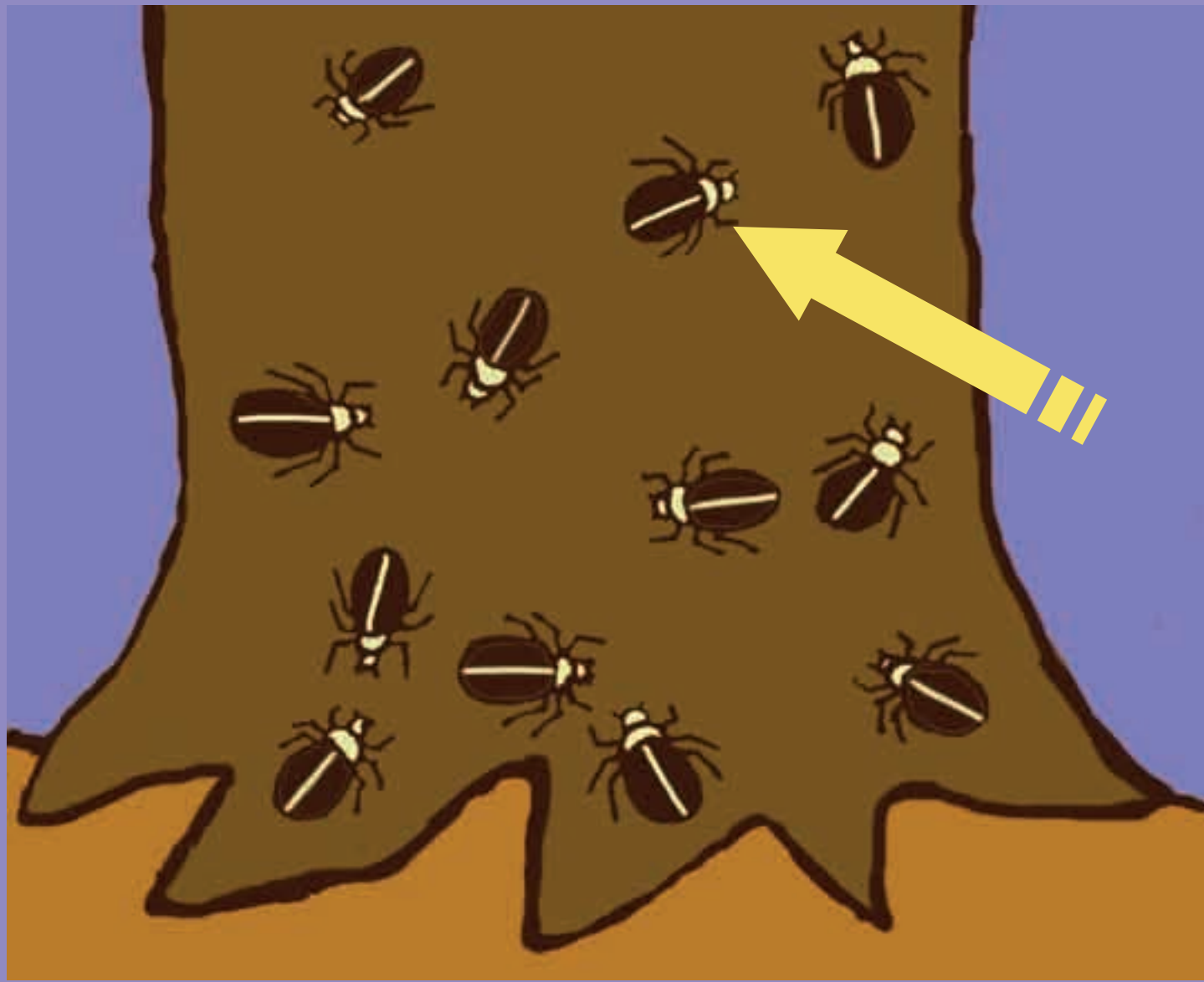
In summary, what are the mechanisms for evolution?

- (1) Natural selection
- (2) Genetic Drift
- (3) Migration (Gene Flow)

All of these mechanisms depend on mutations as the ultimate source of variation.

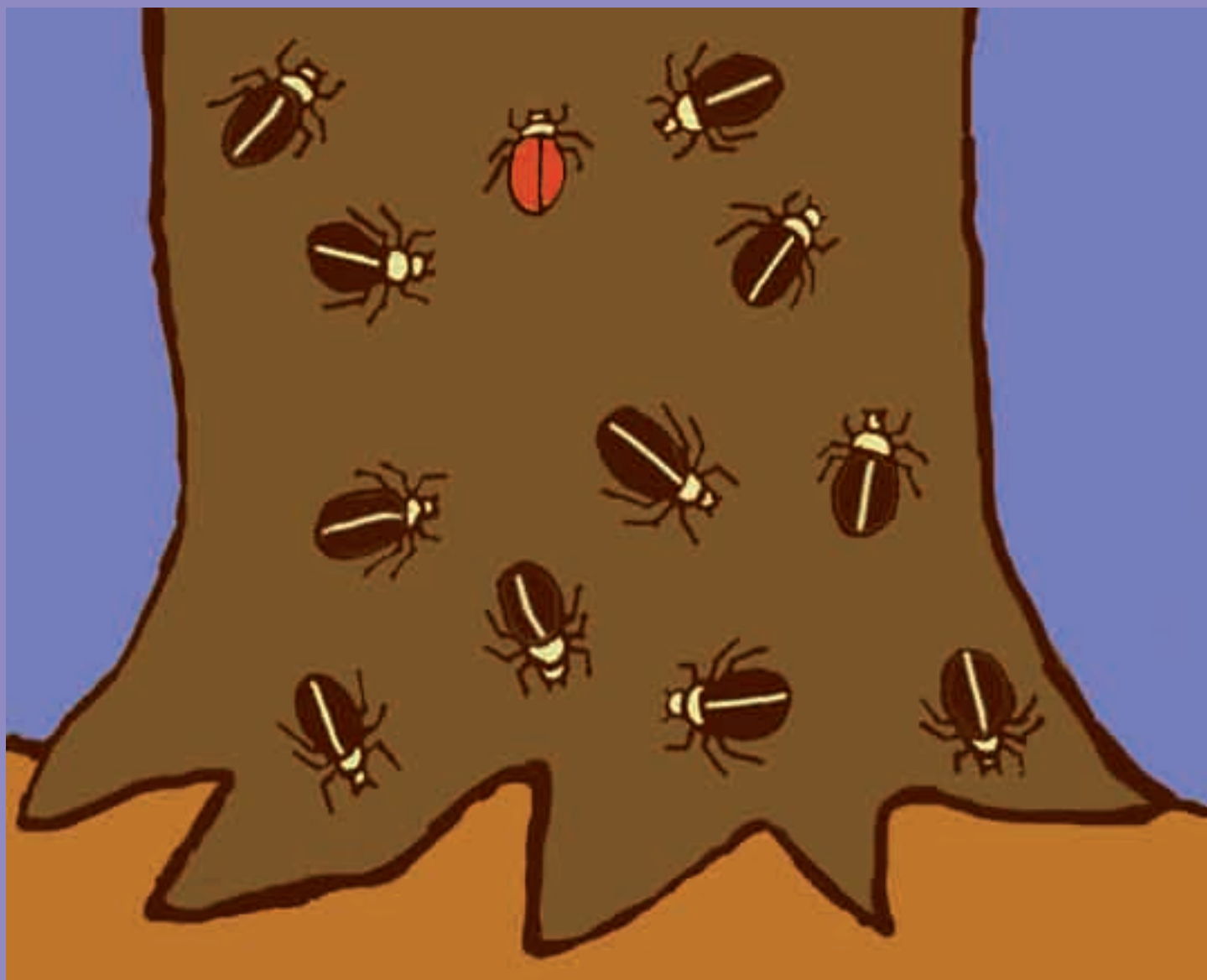


# MUTATIONS



Mutations cause variations in genes. Each variation of a gene is called an allele. For example there may be a gene that determines the colour of a beetle. One allele may cause a beetle to have a dark colour. Another allele of the same gene may cause a beetle to have a light colour.

Suppose a random mutation occurs in the DNA when a beetle's egg is being produced. Usually a mutation will either have no effect or cause the egg to be incapable of development. However, once in awhile, a mutation will result in an offspring with a new trait.



The individual can pass on its mutated gene to its offspring, passing the new trait on as well. In this case, the new trait is a new colour.

## Why do mutations occur?

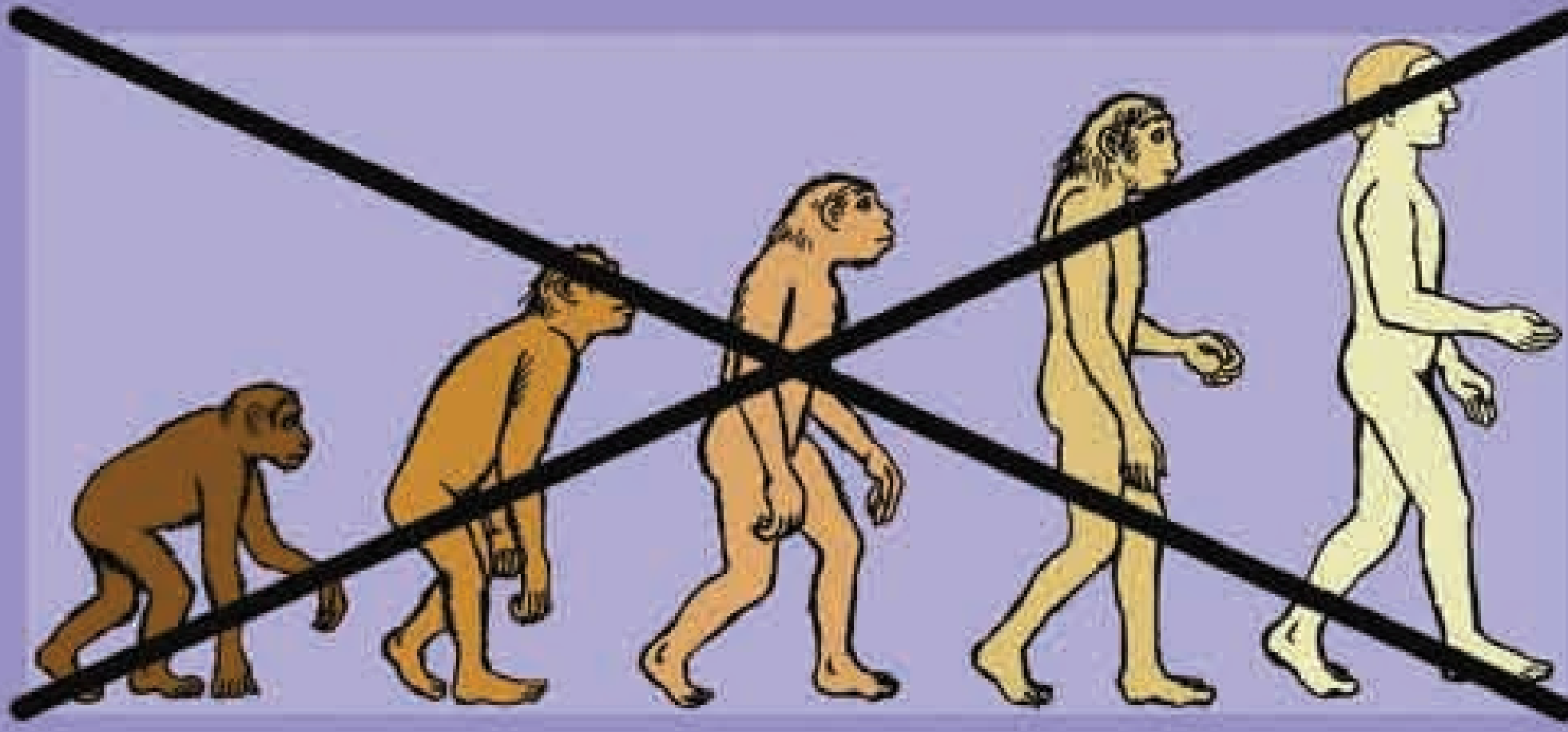
- ✦ Certain chemicals (e.g. benzene) can cause mutations.
- ✦ X-rays and UV radiation can cause mutations.
- ✦ Mutations can also occur due to errors in DNA replication.

Research in these areas are needed so that we can take measures to avoid exposure to things that cause excessive mutation, since this can result in various health problems, such as cancer.

This is a very rare event, but it is the only way new versions of genes are



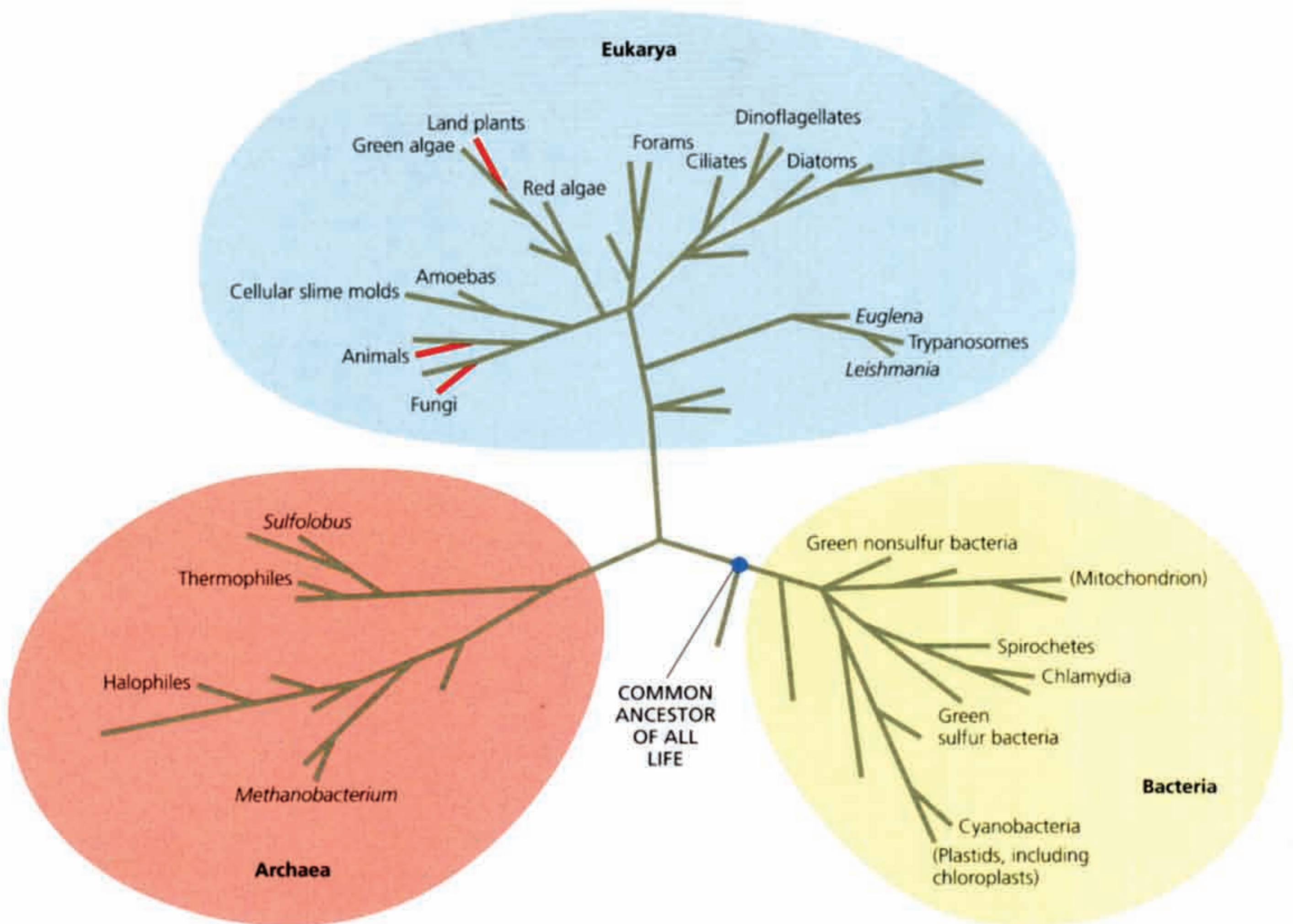
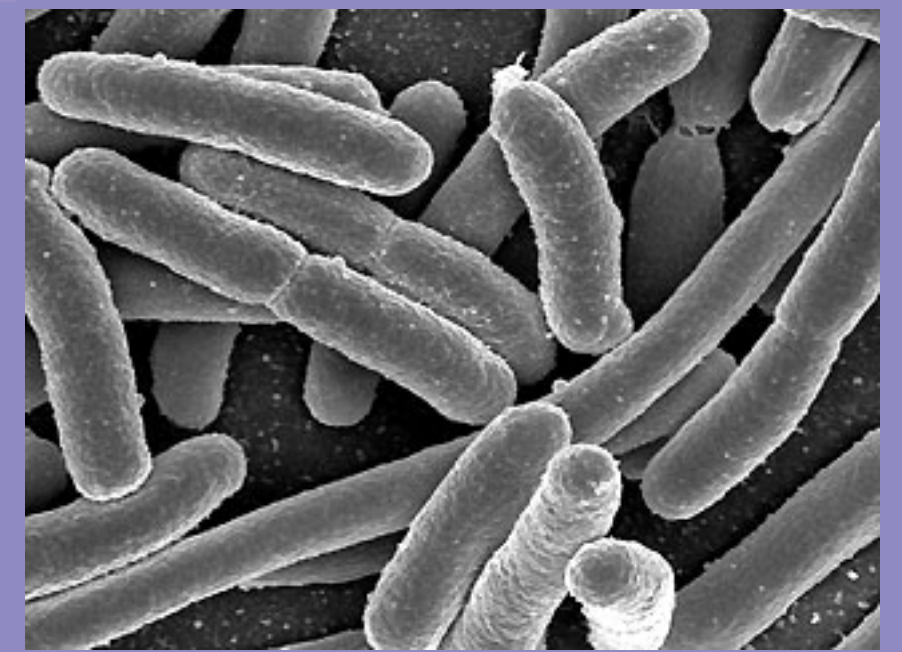
# Evolution is not a march towards perfection



Humans are not more evolved than other species

Evolution is not moving in the general direction of increasing complexity.

Life on earth is still overwhelmingly dominated by unicellular organisms





# Organisms are interdependent

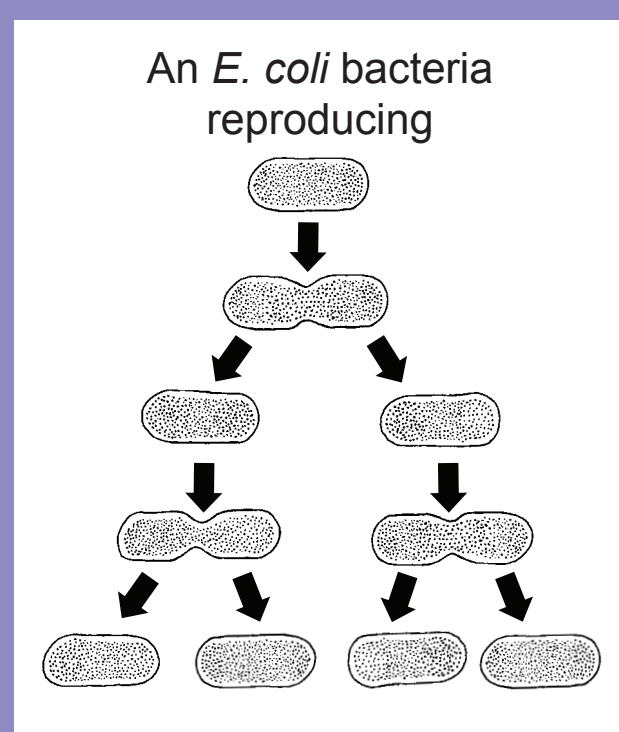
## Humans need bacteria - Bacteria need humans

Many different kinds of bacteria live inside every healthy human body. Bacteria help maintain a healthy digestive system. Problems occur only when certain types of bacteria become too numerous.

Overuse of antibiotics is dangerous to your health



## BACTERIA ARE EVOLVING INSIDE YOUR BODY



It takes only 20 minutes for an *E. coli* bacteria to reproduce.

Bacteria are single-celled organisms that reproduce by simple cell division: the parent cell divides into two identical daughter cells.

Actually, the daughter cells are not exactly identical. When the parent DNA reproduces (to give each daughter cell a copy), there may be one or two mistakes - mutations. These mutations are the source of heritable variations - variations that can be passed on through the generations.

Heritable variations are the source of evolution. Bacteria evolve quickly, since they reproduce quickly.

If the bacteria are exposed to an antibiotic, most of them will die. But there may be a few variant bacteria that will survive and reproduce. Thus natural selection occurs. The population changes into a population that is resistant to the antibiotic.

To avoid bacterial resistance inside your body, avoid antibiotics unless they are absolutely essential. Antibiotics should not be taken for viral infections like the common cold - they don't kill viruses anyway. Also, do not stop taking an antibiotic before the specified number of days - an incomplete dosage will allow more resistant bacteria to survive and reproduce.



# THE ROLE OF CHANCE IN EVOLUTION

When we say evolution happens by chance, we do not mean that it happens without reason - but that the reason is not designed to give the particular effect.

## Are mutations “random”?

What do we mean by RANDOM?

unpredictable?	Mutations are not completely unpredictable.
irrational?	Mutations are not irrational or miraculous.
without cause?	They do not occur without cause.
without purpose?	Yes, mutations are random in the sense that they are without purpose.
disallowing freewill?	

Does this mean that there is no free will?

Mutations are random in the sense that they are causally independent of natural selection.

## CHANCE AND NECESSITY ARE NOT MUTUALLY EXCLUSIVE OPPOSITES

“Everything existing in the universe is the fruit of chance and necessity.”

This is a quote of Democritus from ancient Greece. It is interesting that what he said then has taken on new meaning with our present understanding of evolution by natural selection. Democritus was a materialist philosopher who believed that everything that exists is made of atoms. (The modern Greek government has made him a symbol of a different kind of materialism, depicting him on their bank notes.)



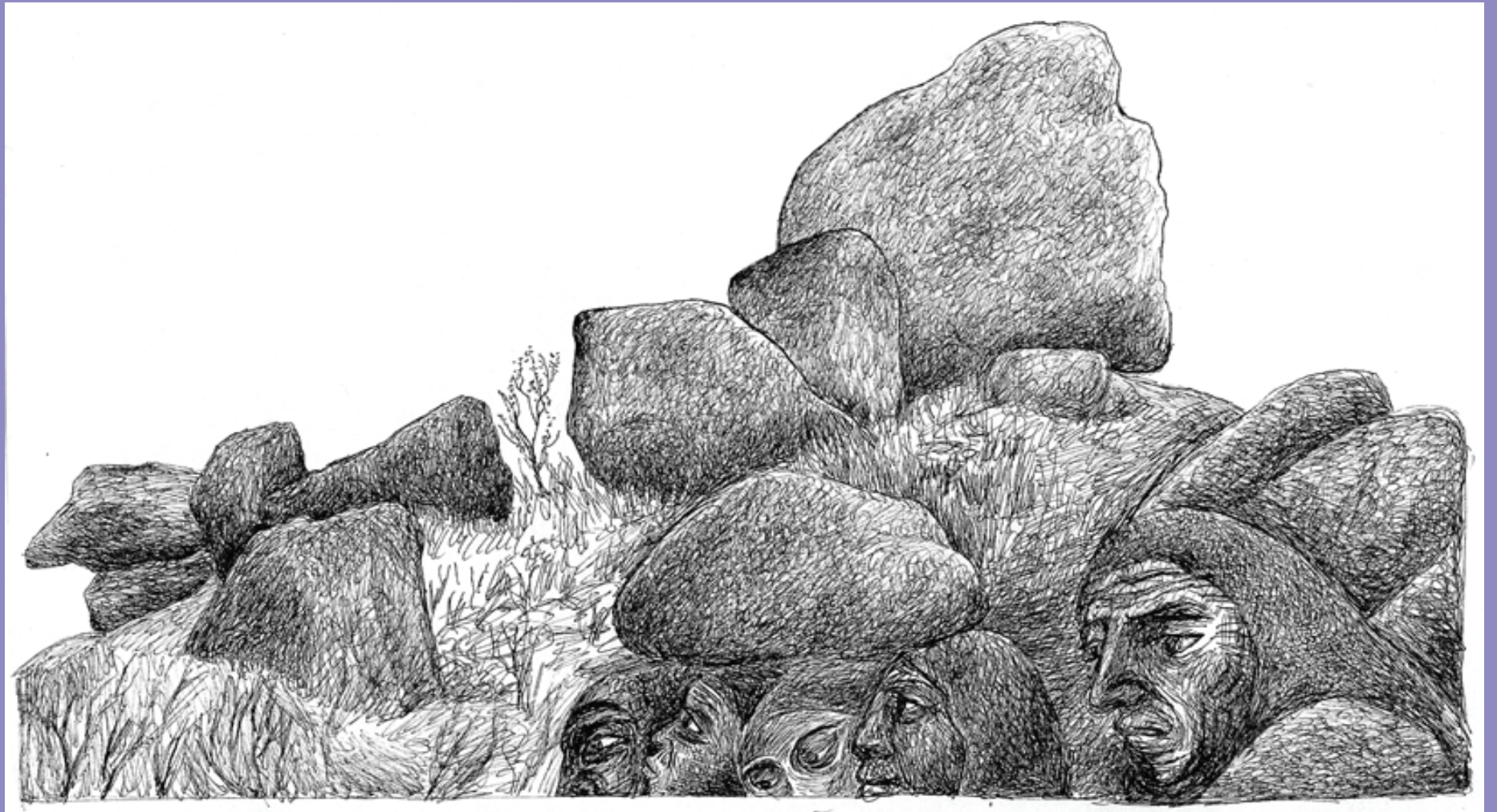


# Returning to the fundamental questions...

## WHO ARE WE?

We all consist of physical processes, interacting in complex systems.

All forms of life are interrelated and interdependent

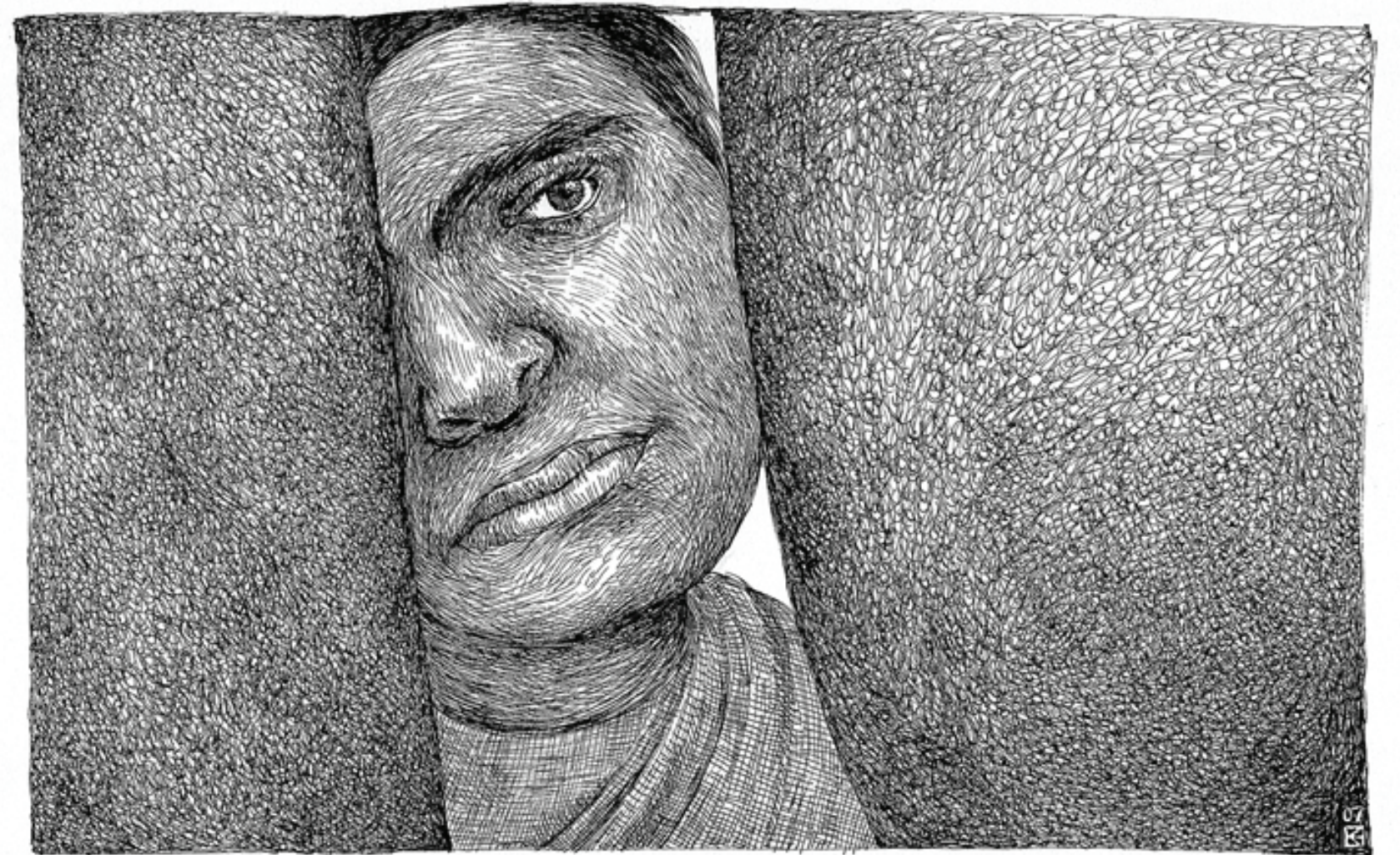


## WHERE DO WE COME FROM?

WE EVOLVED

As life evolved, consciousness also evolved.

EVERYTHING CHANGES

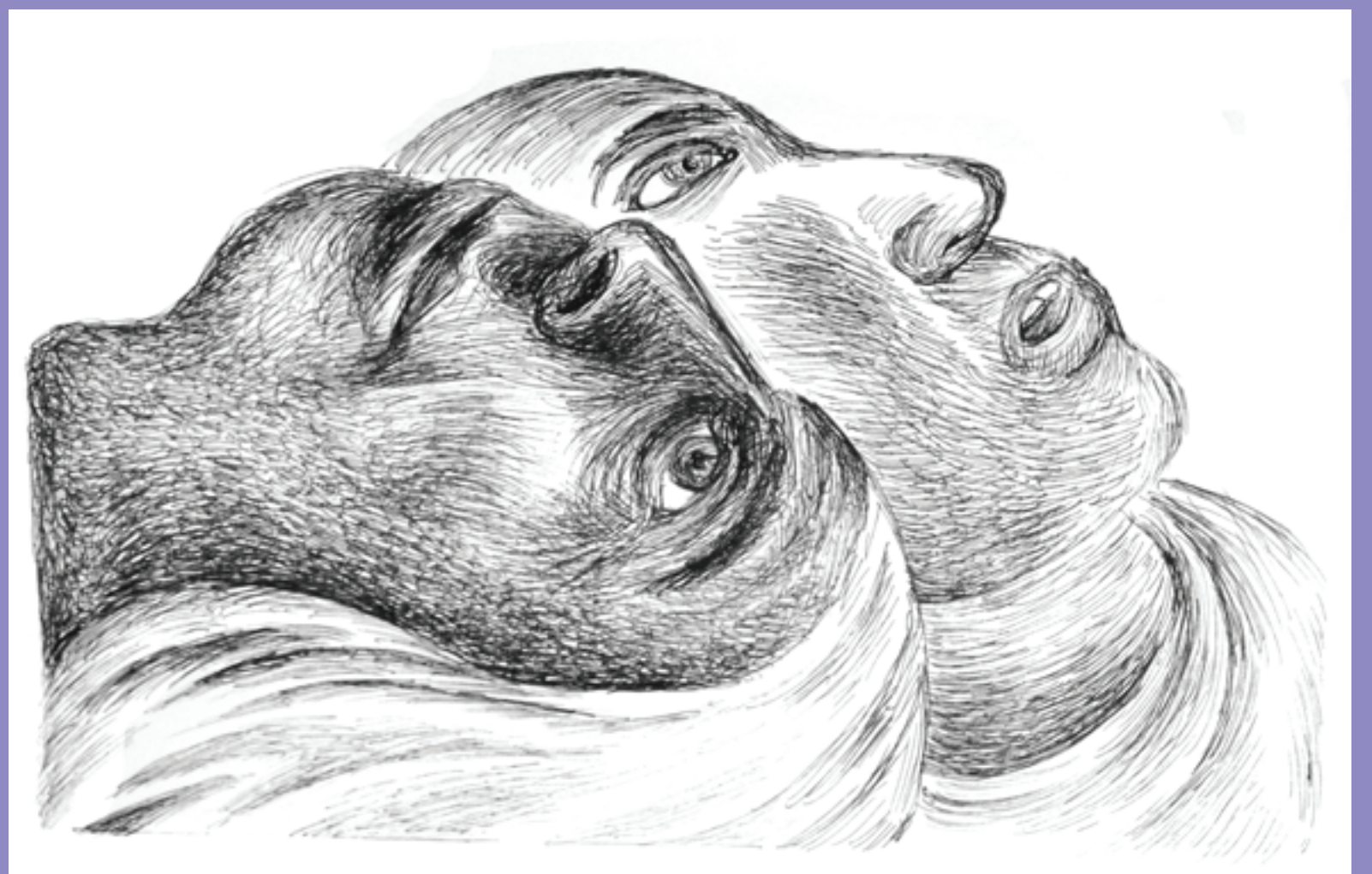


## WHY DO WE EXIST?

BY CHANCE AND NECESSITY

There is no goal in evolution...

We make our own purpose.



Perhaps our freedom lies in the cognition of necessity...



# Why are Darwin's ideas still controversial and difficult to understand?

An understanding of evolution conflicts with our ways of thinking:

We think teleologically

We find it hard to understand that although there is a reason for something, there is no purpose.

We do not think scientifically:

We do not question authority

We think things are separate and individual - it is difficult to see complex interconnections

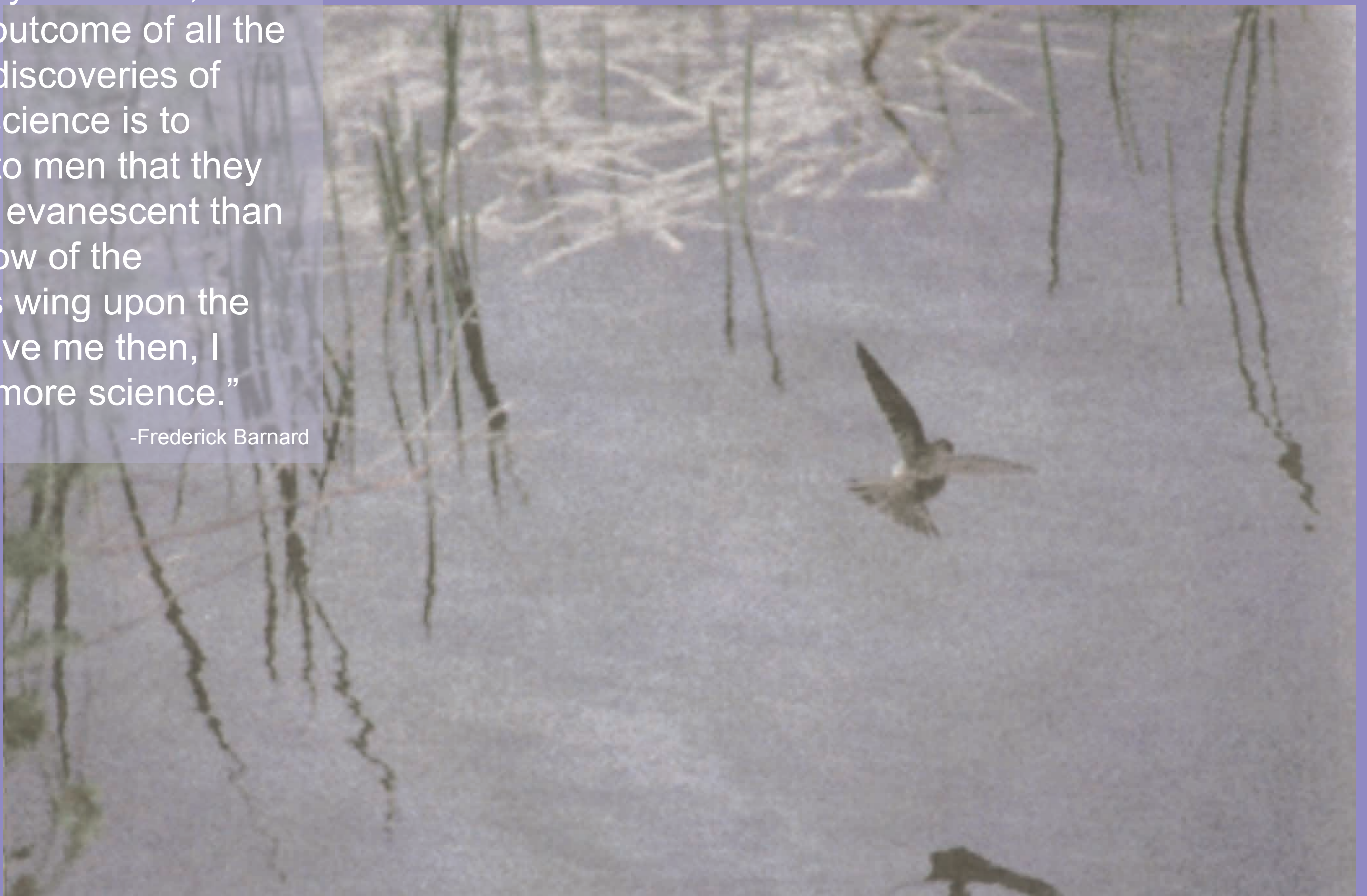
We do not see inherent inner-contradictions

We do not realise that everything changes - perhaps we mistakenly want constancy

## Are we afraid of our mortality?

“Much as I love truth in the abstract, I love my hope of immortality still more; and if the final outcome of all the boasted discoveries of modern science is to disclose to men that they are more evanescent than the shadow of the swallow's wing upon the lake,... give me then, I pray, no more science.”

-Frederick Barnard



But life **is** evanescent...

And if we recognize the need, we may have the freedom to make life meaningful



# WHERE ARE WE GOING?

“There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved. ”

- Darwin (1859)



What is the future of evolution?

And what is the future of human evolution?

Humans have the ability to use artificial selection.

In the future, we may even be able to ‘genetically’ engineer human beings.

But is this desirable? What are the risks? Can misuse be prevented? Who has the right to decide whether and how to engineer humans?

How does artificial selection interfere with natural selection? Can we understand the complex interdependencies of life well enough to guide our future actions?



the earth is a  
moving picture:  
a tale told to  
pass the long  
night of  
inexistence,  
showing that  
since nature  
works through  
mutability  
the essence of  
beauty is that it  
must fade

-Iqbal